PB-234 179

DEMONSTRATION OF THREE RECIRCULATING SWINE WASTE MANAGEMENT SYSTEMS

J. Ronald Miner, et al

Iowa State University

Prepared for:

Environmental Protection Agency

December 1973

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.

PB 234 179

W 74-10198

4. DEMONSTRATION OF THREE RECIRCULATING SWINE WASTE MANAGEMENT SYSTEMS,

5. Report Date

6.

7. Miner, J. R., Hazen, T. E., Smith, R. J., Parker, G. B.

8. Performing Organization Report No.

9. Agricultural Engineering Department. Iowa State University, Ames,

10. EPA Project 13040 ERR

11. Contract/Grant No.

~~12. Sponsoring Organization Environmental Protection Agency~~

13. Type of Report and Period Covered

15. Environmental Protection Agency, Technology Series, report ~~number~~, EPA-660/2-74-009, December 1973. 147 p, 48 fig, 26 tab, 29 ref.

16.

Three waste treatment systems were used to process liquid swine manure so the effluent could be reused as flush-water. Hydraulic transport was effective in removing manure from all eight buildings. Excess liquid from all three systems was applied to adjacent cropland to achieve nutrient utilization as the final disposal step. Reductions in building odors, manure handling labor, and land requirements for final effluent disposal were major goals of the demonstration.

An aeration basin received the manure from two farrowing buildings with a capacity for 14 sows each. As anticipated, solids accumulated in the aeration basin. When the solids content exceeded 4,500 mg/l plugging problems became frequent in the pump and piping system.

A lagoon-aeration basin system served two farrowing buildings with a capacity for 28 sows each. The system performed adequately with only minor mechanical difficulties.

A lagoon-RBC system served four finishing buildings with a total capacity of 700 hogs. Frequent mechanical and biological failure resulted in removal of the RBC from use. Lagoon effluent is being used to flush these buildings with success. Repeated outbreaks of vibrionic dysentery has prompted remodelling two of the buildings and flushing in a gutter covered with slats. ~~(Miner - Oregon State)~~ (EPA)

17a. Descriptors *Waste water treatment, Farm wastes, Waste disposal, *Water reuse, *Hogs, *Hydraulic transportation, *Demonstration farms, Farm lagoons, Aerobic treatment, Biological treatment, Irrigation, Odors, ~~BOD, COD~~, Nitrogen, Biochemical oxygen demand, Chemical oxygen demand.

17b. Identifiers *Swine wastes, *Flushing gutters, Flush tanks, Rotating biological contactors, Anaerobic lagoons, Aeration basins, Land application

17c. COWRR Field & Group 05D, 05E

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

18. Availability Copy Available from GPO Sup Doc as EP1.23:660/2-74-009, $ 2.90; microfiche from NTIS as PB $1.45

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

Abstractor J. Ronald Miner | Institution Oregon State University

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Monitoring, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

EPA REVIEW NOTICE

This report has been reviewed by the Office of Research and Development, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

EPA-660/2-74-009
December 1973

DEMONSTRATION OF THREE RECIRCULATING SWINE WASTE MANAGEMENT SYSTEMS

by

J. Ronald Miner
Thamon E. Hazen
Richard J. Smith
G. Brent Parker

Grant No. 13040 ERR
Program Element 1BB039

Project Officer

Ronald R. Ritter
Chief Grants Administration
U.S. Environmental Protection Agency
1735 Baltimore
Room 249
Kansas City, Missouri 64108

Prepared for

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.90

ia

ABSTRACT

Three waste treatment systems were used to process liquid swine manure so the effluent could be reused as flush-water. Hydraulic transport was effective in removing manure from all eight buildings. Excess liquid from all three systems was applied to adjacent cropland to achieve nutrient utilization as the final disposal step. Reductions in building odors, manure handling labor, and land requirements for final effluent disposal were major goals of the demonstration.

An aeration basin received the manure from two farrowing buildings with a capacity for 14 sows each. As anticipated, solids accumulated in the aeration basin. When the solids content exceeded 4,500 mg/l, plugging problems became frequent in the pump and piping system.

A lagoon-aeration basin system served two farrowing buildings with a capacity for 28 sows each. The waste treatment system performed adequately with only minor mechanical difficulties.

A lagoon-RBC system served four finishing buildings with a total capacity of 700 hogs. Frequent mechanical and biological failure resulted in removal of the RBC from use. Lagoon effluent is being used to flush these buildings with success. Repeated outbreaks of vibrionic dysentery has prompted remodelling two of the buildings and flushing in a gutter covered with slats. The manure removal from the gutter has been satisfactory; however, the pigs' use of the slotted area has not been as reliable as when the flush water was accessible to them.

This report was submitted in fulfillment of Demonstration Grant 13040 ERR, under the partial sponsorship of the Office of Research and Development, Environmental Protection Agency.

CONTENTS

Page

Abstract ii

List of Figures v

List of Tables viii

Acknowledgements x

Sections

I Summary and Conclusions 1
  Buildings 1
  Waste treatment 4
  Pumping characteristics 6
  Effluent quality 7
  Maintenance 7
  Conclusions 8

II Recommendations 12

III Introduction 13
  Flushing gutter concept 13
  Rotating biological contactor 15
  System integration 16
  Project objectives 17

IV Description of Systems 18
  Aeration basin system 18
  Lagoon-aeration basin system 25
  Rotating biological contactor system 25

V Results and Discussion, July 1971 through May 1972 35
  Aeration basin system 35
    Historical account of operation 35
    Water quality 37
  Lagoon-aeration basin system 49
    Historical account of operation 49
    Water quality 52
  Rotating biological contactor system 64
    Historical account of operation 64
    Water quality 71

VI Evaluation of the Original System 90
  Manure-animal separation 91
  Manure removal from buildings 92
  Treatment of the manure 92

VII Systems Modifications and Evaluations 96
    Aeration basin system 96
        Induced aspiration aeration device 96
    Lagoon-aeration basin system 104
    Rotating biological contactor system 104
        RBC flow rate studies 104
        Chlorination of flush water 105
        Flushing gutter modifications 106
    Irrigation system 106

VIII References 109

IX Publications and Patents 112

X Appendices 113

FIGURES

No.		Page
1	Schematic Diagram of the Three Hydraulic Waste Management Systems	2
2	Details of the Flush Tanks	19
3	Flush Tank Similar to the Ones in the Three Systems	20
4	Details of the Aeration Basin System	22
5	The 12 m Aeration Basin	24
6	Details of the Lagoon Aeration Basin System	26
7	The 6 m Aeration Basin	28
8	Details of the RBC System	29
9	Details of the RBC	32
10	BOD_5 vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	38
11	COD vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	39
12	Total and Volatile Solids vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	42
13	Total Phosphate Conc. vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	43
14	Chloride Conc. vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	44
15	Dissolved Oxygen Conc. vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	46
16	pH vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	47
17	Ammonia and Nitrate Conc. vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	48
18	Organic Nitrogen Conc. vs. Time for the 12 m Aeration Basin Effluent, August 1971 to May 1972	50

No. Page

19 Lagoon Effluent and 6 m Aeration Basin Effluent BOD_5 Concentration vs. Time for the Period July 1971 to May 1972 54

20 Lagoon Effluent and 6 m Aeration Basin Effluent COD Concentration vs. Time for the Period July 1971 to May 1972 55

21 Lagoon Effluent and 6 m Aeration Basin Effluent Total and Volatile Solids Concentrations vs. Time for the Period July 1971 to May 1972 56

22 Lagoon Effluent and Total Phosphate Concentrations vs. Time for the Period July 1971 to June 1972 58

23 Total Phosphate Concentration vs. Time for the 6 m Aeration Basin Effluent for the Period July 1971 to May 1972 59

24 Chloride Concentration vs. Time for the Lagoon-Aeration Basin System Effluent for the Period July 1971 to May 1972 60

25 Lagoon Effluent and 6 m Aeration Basin Effluent pH vs. Time for the Period July 1971 to May 1972 61

26 Lagoon Effluent and 6 m Aeration Basin Ammonia Concentration vs. Time for the Period July 1971 to May 1972 62

27 Lagoon Effluent and 6 m Aeration Basin Effluent Nitrate Concentration vs. Time for the Period July 1971 to March 1972 63

28 Lagoon Effluent and 6 m Aeration Basin Dissolved Oxygen Concentration vs. Time for the Period August 1971 to May 1972 65

29 Lagoon Effluent and 6 m Aeration Basin Effluent Organic Nitrogen Concentration vs. Time for the Period July 1971 to April 1972 66

30 RBC Overflow for Wet Well Water Level Control 68

31 Influent and Effluent BOD_5 Concentration vs. Time for the RBC During the Period July 1971 to May 1972 74

32 Influent and Effluent COD Concentrations vs. Time for the RBC During the Period July 1971 to May 1972 75

33 Influent and Effluent Temperature vs. Time for the RBC During the Period July 1971 to May 1972 76

No. Page

34 Long Term BOD Results Obtained by Analysis of RBC Influent Samples on February 28 and July 31, 1972 77

35 Influent and Effluent Total Solids and Volatile Solids Concentrations vs. Time for the RBC During the Period July 1971 to May 1972 79

36 Influent Dissolved Oxygen Concentration vs. Time for the RBC During the Period January to April 1972 80

37 Effluent Dissolved Oxygen Concentration vs. Time for the RBC During the Period August 1971 to May 1972 81

38 Influent and Effluent Nitrate Concentrations vs. Time for the RBC During the Period August 1971 to March 1973 83

39 Influent and Effluent Ammonia Concentrations vs. Time for the RBC During the Period July 1971 to May 1972 84

40 Influent and Effluent Organic Nitrogen Concentrations vs. Time for the RBC Effluent for the Period July 1971 to May 1972 85

41 Influent Chloride Concentrations vs. Time for the RBC During the Period July 1971 to May 1972 86

42 Effluent Chloride Concentration vs. Time for the RBC During the Period July 1971 to May 1972 87

43 Influent Total Phosphate Concentration vs. Time for the RBC During the Period July 1971 to May 1972 88

44 Effluent Total Phosphate Concentration vs. Time for the RBC During the Period July 1971 to May 1972 89

45 The Aerator Used for the Period November 1972 to June 1973 98

46 Temperature vs. Time for the Mixed Liquor in the Aeration Basin, and of the Surrounding Air. The Time Period Covered in Each Case is From Immediately Before an Addition of Slurry to a Few Hours After a Second Addition 100

47 COD vs. Time of the Mixed Liquor in the Basin During the Aerob-A-Jet Study 103

48 Revised Flushing Gutter and Slat Arrangement Used in Two Finishing Buildings 107

TABLES

No.		Page
1	Summary of the Three Swine Waste Systems Evaluated at the Bilsland Memorial Research Station	1
2	Details of the Aeration Basin System	23
3	Details of the Lagoon Aeration Basin System	27
4	Details of the RBC System	30
5	Details of the RBC	33
6	Effluent Water Quality From the 12 m Aeration Basin Serving Two Farrowing Buildings, 14 Pens per Building, August 1971 to April 1972, Average Values mg/l	40
7	Constituent Removal Efficiency of the 12 m Aeration Basin Serving Two Farrowing Buildings, 14 Pens per Building, July 22 to November 2, 1971	40
8	Waste Treatment Performance of the Lagoon-Aeration Basin System, July 22, 1971 to March 16, 1972 When Irrigation Began	53
9	Waste Treatment Performance of the RBC System During the Period July 1971 to April 1972	72
10	Strength of Waste Added to the Aeration Basin During the Aerob-A-Jet Study (mg/l)	101
11	Strength of Waste in the Aeration Basin During the Aerob-A-Jet Study (mg/l)	102
12	RBC Performance Under Various Flow Rates After Revitalization	105
13	Weights of Animals in the Aeration Basin System for Various Dates	116
14	Weight of Animals in the Lagoon-Aeration Basin System for Various Dates	117
15	Weight of Animals in the RBC System for Various Dates	118
16	RBC Influent Water Analysis Data	121

No.		Page
17	Results of Water Quality Analyses Conducted on the RBC Lagoon Supernatant Including the Time this Water was not Serving as RBC Influent	125
18	RBC Influent Temperature and Dissolved Oxygen Data	126
19	RBC Effluent Water Analysis Data	127
20	RBC Effluent Temperature and Dissolved Oxygen Data	131
21	Twelve Meter Aeration Basin Water Analysis Data	132
22	Twelve Meter Aeration Basin Temperature and Dissolved Oxygen Data	135
23	Anaerobic Lagoon Supernatant of the Anaerobic Lagoon-Aeration Basin System Chemical Data	136
24	Anaerobic Lagoon Supernatant of the Anaerobic Lagoon-Aeration Basin System Temperature and Dissolved Oxygen Data	140
25	Six Meter Aeration Basin Water Analysis Data	141
26	Six Meter Aeration Basin Temperature and Dissolved Oxygen Data	145

ACKNOWLEDGEMENTS

This project was conducted at the Bilsland Swine Genetics Research Station as part of the overall animal waste management program at Iowa State University. This work would not have been possible without the substantial direct and related project support provided by the Iowa Agriculture and Home Economics Experiment Station, Iowa State Engineering Research Institute, the Environmental Protection Agency, and the Public Health Service.

The operation of the waste treatment systems, data collection, and evaluation during the initial testing program were part of the graduate training program of Howard F. Person. His diligent work is gratefully acknowledged. Subsequent evaluation and system modifications were largely performed by G. Brent Parker. The design of the systems, construction, report preparation, and overall project direction were the responsibility of Agricultural Engineering Department staff members Thamon E. Hazen, Arthur R. Mann, J. Ronald Miner, and Richard J. Smith.

The rotating biological contactor was designed, fabricated, installed, and modified by the Autotrol Corporation of Milwaukee, Wisconsin. Frank Koehler and Robert J. Hynek were the men who bore major responsibility in this portion of the project.

R. S. Blough and Kenneth Joslin of Fairfield Engineering Co., Fairfield, Iowa contributed significantly to the work done on the Aerob-A-Jet. The patience and cooperation of the personnel responsible for the daily operation of the swine genetics research station has been appreciated. Particular gratitude is due Mr. Joe T. Morrissey and Dr. Lauren Christian for their cooperation.

This project was supported in part by a Demonstration Grant from the Environmental Protection Agency. The assistance and counsel provided by Mr Ronald R. Ritter, Project Officer, is gratefully acknowledged.

SECTION I

SUMMARY AND CONCLUSIONS

Three waste management systems serving a total of eight confinement buildings were developed to serve part of a swine genetics research station. Four of the buildings are used for farrowing and the other four for growing-finishing. The flushing gutter concept was used for hydraulic cleaning and transport of the manure to the treatment facilities. In all systems the treated effluent was returned to the building for flushing the gutters and the excess liquids applied to adjacent land using conventional irrigation equipment. The three systems are summarized in Table 1 and Figure 1.

Table 1. SUMMARY OF THE THREE SWINE WASTE SYSTEMS EVALUATED AT THE BILSLAND MEMORIAL RESEARCH STATION.

System	Buildings served	Animal capacity	Treatment system
Aeration basin	2 farrowing	28 sows and litters	Aeration basin
Lagoon-aeration basin	2 farrowing	56 sows and litters	Anaerobic lagoon-aeration basin
RBC	4 finishing	700 hogs	Anaerobic lagoon-rotating biological contactor

BUILDINGS

The eight buildings are similar to the extent that each had adjacent pens that form a single row, with a common gutter passing through all the pens. The pen floors slope five percent toward the gutter. The gutters in the farrowing pens are 61 cm wide while those in the growing-finishing buildings are 77 cm wide. During most of the project period, all gutters were 7.62cm deep and had 0.4-percent slope the length of the building. A syphon-activated flush tank, located at the upper

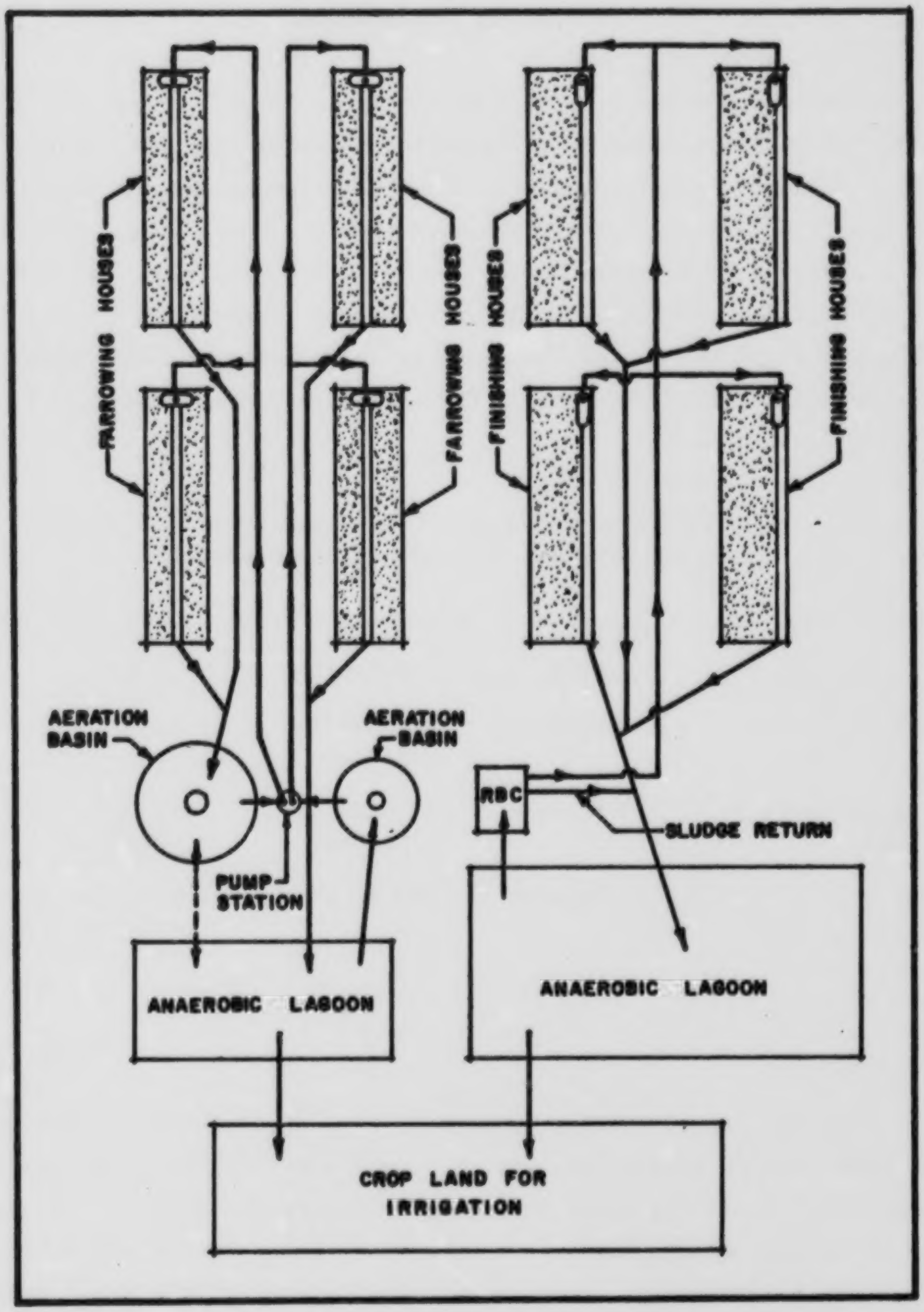

FARROWING HOUSES
FARROWING HOUSES
FINISHING HOUSES
FINISHING HOUSES
AERATION BASIN
AERATION BASIN
PUMP STATION
RBC
SLUDGE RETURN
ANAEROBIC LAGOON
ANAEROBIC LAGOON
CROP LAND FOR IRRIGATION

Figure 1. Schematic diagram of the three hydraulic waste management systems.

end of each gutter discharged about 400 liters of water in approximately 40 seconds whenever the liquid depth in the tank reached 46 cm. The frequency of flushing was controlled by the rate at which water was pumped into the tanks. At the lower end of the gutters, the carriage water and transported manure dropped into a 15 cm plastic sewer line and flowed by gravity to the waste treatment system.

Recently, in two of the growing-finishing buildings, the gutter was deepened, its cross section modified, its slope was increased to one percent, and the gutter was covered by slats at the pen floor level. A modified syphon was installed that increased the discharge rate by approximately 50 percent.

The facilities have been managed in accordance with the needs of the swine genetics research station, thus they have not been filled to capacity throughout the study period. Overall, the buildings have been satisfactory in terms of waste management. Little hand labor has been expended in manure removal. Odor levels have generally been acceptable. There is some evidence that the open flushing gutter increased the speed that an outbreak of bloody scours was propagated through a building, but evidence showing that the flush water was the cause of the disease is lacking.

The flush tanks operated successfully throughout the project. To maintain clean buildings, a 30-minute flushing interval was used. The only maintenance required has been the annual removal of slime that develops on the outlet pipe and bell. This growth of slime increased the time required to empty the tanks from one to two minutes. Removal of the slime by scraping the bell and pipe surfaces returned the flush tank to normal operation.

The hogs in the finishing buildings were diligent in their use of the gutters. When the flush tanks discharged, the hogs gathered in the gutter to root in the water as well as to defecate and urinate. The area that the hogs used to sleep upon, and the hogs themselves, remained clean and dry.

The sows in the farrowing building were not as diligent in their use of the flushing gutters as the finishing animals. In the buildings served by the lagoon-aeration basin system the pens are 1.2 m wide. A 180 kg sow is about 1.5 m long. This means that it is difficult for the sow to turn around in the pen, nor can she get the full length of her body in the gutter. The result was that the sows would root in the running water but defecated and urinated in the pen area.

The pens in the buildings served by the aeration basin system are wide enough to accomodate the entire length of the sow in the gutter. The sows defecated and urinated in the gutter about 50-75 percent of the time. The nursing area usually remained clean. The feces deposited in the rest area were periodically scraped into the gutter.

A wedge of solids about 2 to 4 cm high by 20 to 30 cm wide developed along the outside edge of the channel in the finishing buildings. This wedge remained about the same until the average animal weight reached 75 kg, then the wedge of solids began to widen at the lower end of the gutter. By the time the water reached the lower end of the gutter it lacked enough kinetic energy to maintain the solids in suspension and roll the larger solids down the gutter. The recent gutter modifications in the two growing-finishing buildings have verified that an increase in the channel slope or a combination of increased slope and discharge are necessary to obtain the desired manure transport capacity of the flowing water.

WASTE TREATMENT

All three systems of waste treatment are similar in that liquid manure is biologically treated so the liquid fraction can be reused as a hydraulic transport medium. Excess liquids are applied to cropland along with residual solids. Thus, odor emission and effluent pumping characteristics become important parameters as well as returned water quality.

Odors

In the aeration-basin system raw manure from the farrowing houses decomposes aerobically. There were no appreciable odors near the aeration basin nor were there any detectable odors other than a slight "earthy smell" from the returned effluent while the aerators were in operation. When the 5-hp floating surface aerator was removed an "acetic" odor was noticeable within 3 m of the flush tanks. There were no detectable odors 15 m from the aeration basin; however, after the aerator was re-installed in March, 1972, a slight odor was present at the aeration basin for the first four days. An Aerob-A-Jet aerator was installed in the 12 m aeration basin in the late fall of 1972. This unit was able to operate through the winter without icing. No odors were detected at the rim of the basin when this unit was in action.

In the lagoon-aeration basin system, raw manure from the farrowing houses is first discharged into an anaerobic lagoon and then flows into the aeration basin. No odors were detectable 15 m from the lagoon or aeration basin from start up until May, 1972. During April and May, outside temperatures and lagoon water temperatures began to increase along with anaerobic activity. A slight odor was liberated from the lagoon at this time and until the first week in June. No obnoxious odors were detected 15 m from the aeration basin. The aeration basin effluent did not emit odors from start up until the first week in March, 1972 even though the aerator was removed for modification during the first week in November. During the first week in March, a slight odor was detectable up to 6 m from the flush tanks in the farrowing buildings. This odor dissipated when the floating aerator was re-installed.

No detectable odors were emitted from the anaerobic lagoon connected with the RBC system from start up until April of 1972 when anaerobic activity increased. The odor emitted was detectable 60 to 90 m from the lagoon area and gradually diminished until June when odor was not detectable beyond 10 m.

The RBC, on the other hand, was a nearly constant source of odor. Lagoon effluent falling from the overflow pipe into the wet well agitated the water and liberated hydrogen sulfide gas. This produced an obnoxious odor that could be detected some distance from the RBC building during the first four weeks of operation. The odor level near the RBC remained low for the next three months. During the first week of December, an odor similar to that of an outdoor privy was detectable inside the RBC building and within 10 m of the building. This odor persisted until the first week in June, 1972. While the RBC effluent is not odorless, no objectionable odor problems were encountered in the finishing buildings.

No objectionable odors were emitted during irrigation of excess water from any of the three systems to adjacent crop land.

PUMPING CHARACTERISTICS

An important effluent characteristic for a reuse situation is that the water be suitable for handling with commercially available pumps and plumbing equipment. The effluent from the RBC satisfied this criteria from start up until mid-January, 1972. During mid-January deposits of calcium carbonate were observed in the disk section of the RBC. By April the return flow rate to the buildings had decreased by 33 percent. Inspection of pipes revealed a deposit of calcium carbonate. A one-percent solution of acetic acid was circulated through the recycle lines to dissolve the calcium carbonate.

The effluent returned to the farrowing buildings in the lagoon-aeration basin system has caused no major plugging problems when the hydrant valves are fully open. When the hydrant was partially closed to decrease the flushing frequency, solids settled in the return line and clogged the valve. Flow was maintained by fully opening the valve once or twice daily. The valves are normally left fully open and checked daily. The inlet to the pump is protected with a 1-cm mesh wire screen to prevent large particles from entering the pump. Hog hairs and dead grass tend to plug this screen to the extent that daily screen cleaning is required.

The system with the 12-m aeration basin functioned well from start up until mid-October of 1971, when the total solids concentration reached 4560 mg/1. These solids, aerobic bacteria, manure solids, and hog hairs plugged the pump inlet screen and hydrant valves. As the solids concentration increased above 4500 mg/1 the return line had to be back washed with clear water once or twice per day to remove the solids that clogged the hydrant valves. Daily cleaning of the inlet screen was also required.

EFFLUENT QUALITY

All three waste treatment systems were designed to produce an effluent suitable for reuse and for application to cropland. Removal of COD, nitrogen, solids, phosphates, and other materials was desirable as a means of reducing the land area required for effluent disposal.

The aeration basin system received a variable waste load due to the farrowing pattern of the station. This was anticipated in the original design. Constituent removal efficiencies were, however, acceptable. When the aerator was in operation, a high level of dissolved oxygen was maintained and organic matter significantly reduced.

The lagoon-aeration basin system also received a waste load dependent upon building utilization patterns. Due to the short detention time and low solids concentration, the 6-m aeration basin did not alter the effluent quality significantly except to raise the dissolved oxygen concentration to 6 mg/l or above when it was in operation. Overall, however, high organic matter removal rates were achieved.

The lagoon-RBC system served the four finishing buildings with a total capacity of 700 hogs. Although the buildings were not fully occupied throughout the period, this system handled the greatest waste load. The RBC, like the surface aerator, had little effect on the return water quality. The lagoon was effective in its biological treatment.

MAINTENANCE

The major maintenance problems associated with the 12-m aeration basin system were the pumping problems discussed earlier. The lagoon-aeration basin system has required little maintenance. The vegetation around the lagoon and aeration basin is mowed periodically.

The motor mounts on both surface aerators fractured and had to be replaced on two occasions. They were returned to the manufacturer for modification and no problems with the motor mount fracture have occurred since.

Occasionally corn leaves, grass, and muskrats get caught in the aerators and must be removed. This involves pulling the aerator to one side of the aeration basin and removing the clogging material from the impeller.

The RBC system has presented more problems than the other two systems. Most of the maintenance problems have been related to the RBC itself. The most troublesome problem has been the removal of calcium carbonate deposits. Lagoon maintenance has been periodic mowing of the vegetation that grows around it.

CONCLUSIONS

1. Hydraulic flushing was demonstrated to be effective as a low-labor waste removal practice. Animals and buildings remained clean and odors within the buildings were low regardless of whether the recycled wastewater used for flushing was anaerobically or aerobically treated. However, the aerobically treated wastewater was the more desirable from a strictly human reaction viewpoint.
2. Added design information was gained relating quantity and discharge rate of the flushing water with geometry of the hydraulic channel and the method of feed processing. Except for very short runs, channel slopes of less than one percent were hydraulically inefficient for manure removal. Binders used in pelleted feeds resulted in a manure that required a noticeably higher flushing velocity for good removal. Flushing was equally effective in manure removal whether under slatted floors or in channels directly accessible by the animals; however, animals trained better to defecate in an accessible channel than over a channel separated by slatted floor sections.
3. Recurrent outbreaks of vibrionic dysentery demonstrated that flushing channels directly accessible to the animals probably

contributed to the spread of such a disease, once introduced. Likewise, they may make subsequent treatment and control more difficult. The station had a prior history of this disease. Outbreaks have not occurred in other similar installations, and no viable organisms were found in the treated wastewater. Introduction or harboring of the disease via the recycled wastewater is not likely. Also, chlorination of the flush water to obtain 3-5 ppm free chlorine residual at discharge did not appear to substantially reduce the transmission potential as the residual was quickly lost on contact with wastes in the gutter. Associated studies where the only liquid available to the animals was anaerobically treated wastewater have shown enlarged lymph nodes in the pigs subjected to post mortem examination. Changes in animal performance have not been significant.

4. Mineral crystallization in the plumbing is a continuing occurrence in anaerobic systems. It is less of a problem with plastic than with metallic materials. The two crystals encountered were magnesium ammonium phosphate and calcium carbonate. The former can be successfully solubilized by treatment of the system with a mild acid (ph $\leq$ 5). The $CaCO_3$ was most noticeable in the disc section of the RBC, accumulating to the point that it severely wore the edges of the disc, and by carry-over into the clarifier, also plugged the transfer pumps. The acid chosen for cleaning was a 1 + 50 dilution by volume of glacial acetic acid, since acetic acid is readily metabolized by anaerobic bacteria.
5. Organic solids were a continuing problem in the mechanically aerated basins, plugging pumps and valves. However, if the aerators were stopped, the floc readily settled suggesting the potential value of the inclusion of sedimentaion in the future design of these systems.
6. No transfer pump was found that we consider meets the needed endurance, cost, and performance criteria. Needed pumping capacities range from 40-160 l/min at up to 15 m of total head. To date

the best performing pump has been an all-plastic, positive displacement type (Jabsco). Irrigation pumps, because of their lower duty and higher capacity, have not presented a similar problem.

7. Anaerobic lagooning, though producing some odor in the early spring, was the simplest, least expensive, most easily managed, and yet seemingly effective method used for treatment of the recycled flush water. The combination of anaerobic-aerobic biological treatment of swine wastes is more effective than either alone. Alone, both processes have definite limitations. The anaerobic process produces an effluent prone to solids deposition upon pumping. The aerobic process is ineffective in decomposing resistant solids such as hog hair and undigested grain.

8. The excess treated wastewater is of sufficiently high organic strength that land disposal by sprinkler distribution appears to be the most feasible. The nutrient content of these wastewaters (N, P, K) rather than the liquid volume determines the rate and area of application, though conventional irrigation equipment can be used. Our findings suggest that phosphorous concentration may govern land area requirements for aerobically treated wastewater whereas either phosphorous or nitrogen may become controlling if anaerobically lagooned. Under the cultural practices of the land adjacent to the animal facilities, approximately 18 hectares or 1 hectare per 250 animals is required for nutrient utilization. Thus, after experience with some systems and investigations of others, we elected to install a stationary electric pump serving a self-propelled irrigation nozzle (big gun) via a single underground PVC main with three appropriately spaced risers. The S-P nozzle travels 400 m delivering 2,780 m^3 over 6 hectares in 24 hours. Up to 15,000 m^3 in three irrigations is applied each year, i.e., April, June, and October. Only one riser will be installed initially. The decision to move the gun to an adjacent strip in future years will be made on the basis of actually measuring the NPK pumped from the lagoon during the first full operating season (1974).

9. The Rotating Biological Contactor as now manufactured is not a suitable piece of equipment for the conditions presently prevailing in intensive livestock production enterprises. It requires management and maintenance schedules not likely to be understood or given by producers, and we found it incapable of effectively treating the high organic strength wastes normally being discharged from livestock buildings.
10. Although simple in engineering terms, present-day livestock producers find the systems demonstrated to be difficult to maintain and operate.
11. The flush tanks, utilized in this project proved fully reliable and presented no operational difficulties.
12. The building design used in this project proved to be superior to conventional swine confinement facilities. Odor and temperature control within the buildings were more easily maintained. Odors emanating from the buildings presented no difficulties.
13. Of the three systems demonstrated, the lagoon-aeration basin proved to be the most desirable both in terms of operational difficulties and cost.

SECTION II

RECOMMENDATIONS

The flushing gutter has been demonstrated to be an effective means of transporting swine manure from a growing-finishing building. To be effective, a flushing gutter should be 60 to 90 cm wide and have a slope of approximately one percent.

Treated effluent is an acceptable medium for use in flushing gutters. Primary quality requirements are that it not be an odor source, that it be neither corrosive nor cause excessive deposition in water lines nor that it contain sufficient solids to plug the plumbing fixtures involved. The disease considerations deserve continued attention.

The lack of reliable pumps, screening devices, and related devices of appropriate size continued to present difficulties in this study. Additional development efforts are recommended to meet this need.

To be successful, a waste management scheme must be compatible with the operation, management, and maintenance skills of the livestock producer. Thus, simplicity is recommended as a criteria for the design of a livestock waste treatment system for which the operator will be primarily an animal husbandryman with only limited interest and training in the operation of sophisticated waste treatment devices.

For the successful operation of a recycling hydraulic waste management system, ultimate disposal of excess liquid to cropland appears the logical solution. More sophisticated criteria are needed to establish maximum application rates which consider soil type, climate, and cropping practices and specific waste constituents.

SECTION III

INTRODUCTION

The trend toward confinement feeding of livestock began as early as 1947 and is well documented.[1,2,3] By 1960, information on functional and basic requirements for swine housing had been developed.[4] As more animals were raised in confinement, more land was used for row crops. This made less land available for field spreading of manure. Manure could not be left to accumulate in the buildings. With this in mind, researchers began to investigate new alternatives for animal waste management.

FLUSHING GUTTER CONCEPT

In 1963 a system for hydraulic removal of swine manure from a confinement finishing building by continuously flushing fresh water into dunging channels was first used at Iowa State University.[5,6] Taiganides[7] characterized the swine wastes from finishing buildings and tested a laboratory model of an anaerobic digester.

In 1965, Knight[8] characterized the performance of the cage rotor in an oxidation ditch. By 1966 the properties of farm animal excreta were published from work done by Taiganides and Hazen.[9] Merkel[10] was able to demonstrate that manure is a significant source of odor in a swine confinement building and quick manure removal significantly decreases the odor level in the building.

Various systems for hydraulic transport, treatment, and disposal of swine wastes were investigated at the confinement finishing building referred to as Unit K at Iowa State University. A detailed account of the evolution of these systems is given by Smith.[11] The original waste management system, constructed in 1960, consisted of a dunging channel equipped with mechanical scrapers that ran the length of the building. The manure was removed by these scrapers and discharged into a storage tank. The manure was pumped into a spreader truck that spread the manure on the nearby farm land. The operation of this system was not satisfactory.

the 0.61-m porous cup samples often had nitrate nitrogen levels above 200 mg/1 when the application rate exceeded 2200 kg/ha-yr of N.[17]

ROTATING BIOLOGICAL CONTACTOR

Antonie and Welch[18] described a device called a Rotating Biological Contactor (RBC). This device consists of a series of circular disks mounted on a horizontal shaft. The lower 1/3 to 1/2 of these disks are immersed in waste water. The disks are rotated so that they are alternately immersed in the waste water, picking up organic material and then exposed to air. A slime growth develops on these disks which decomposes the organic material. Some of the advantages claimed for this device include low power requirement (since the disks are balanced on the shaft and turn at 2-4 rpm), few fast moving parts, 80-90 percent reduction of BOD_5, few maintenance problems, and satisfactory operation even at low wastewater temperatures.

Welch[19] reported that the RBC was useful for treating concentrated wastes. His work demonstrated that the dissolved oxygen (DO) concentration in the disk chamber liquor must be above 1 mg/1 for good COD removal.

Joost[20] reported being able to remove 90 percent of the BOD from a domestic waste with a Rotating Biological Surface with a hydraulic detention time of less than 45 minutes. He pointed out that the RBC operates with a low food to microorganism (F/M) ratio ranging from 0.02-0.05. This compares to a F/M ratio of 0.3 for activated sludge processes. This, and because the organism cannot be washed from the system, enables this system to withstand shock loading. He also stated that the RBC will remove organic material even when the system is overloaded.

Borchardt[21] presented some historical background of the rotating biological contactor concept. He also reported that a three-stage RBC with 1.2-m diameter disks loaded "nominally" (probably with a domestic waste) removed 89-94 percent for the BOD_5 during warm weather and 85-89 percent of the BOD_5 during cold weather. The hydraulic detention time was 21 minutes.

SYSTEM INTEGRATION

Hydraulic manure transport systems for use in confinement swine buildings have been developed by researchers at Iowa State University over the past several years. The basic system incorporates a shallow gutter through each pen which is periodically flushed with water. In recent work, the flush water used has been effluent from a treatment process, thus recycled water. Pigs have been observed to adapt well to this system by depositing most of their manure and urine directly in the gutter. Thus, it can be removed periodically by the flushing and results in less manure decomposing in the pens, cleaner animals, and a generally more pleasant environment within the building. Pig performance in terms of weight gain, feed efficiency, and general health has simultaneously been good.

In this project several components for handling swine manure were integrated into the construction of three different waste handling systems at the Bilsland Memorial Research Station near Madrid, Iowa. These systems were placed into operation in late July,1971, and what follows is a report on, and evaluation of, their performance.

The three systems serve a total of eight confinement buildings which are part of a swine genetics research station. These buildings were in use for swine production prior to this project; the manure was manually scooped from the pens and loaded into a conventional manure spreader. The buildings were extensively modified as part of this project, four of the buildings remodeled for farrowing and the other four for growing-finishing. All use the flushing gutter concept for hydraulic cleaning and transport of the manure to the treatment facilities. In all systems, the treated effluent is returned to the building for flushing the gutters, and the excess liquids applied to adjacent land by sprinkler irrigation equipment.

The "Aeration Basin System" serves two farrowing buildings, each housing 14 sows and litters. Treatment of the hydraulic wastes is by a detention structure with a surface aerator. The "Lagoon-Aeration Basin System" also serves two farrowing buildings, but with 28 pens per building.

Treatment of the hydraulic wastes in this system, however, is by an anaerobic lagoon followed by a detention structure with a surface aerator. The third system serves the four growing-finishing buildings which have capacity to house 700 hogs. Waste treatment is, successively, by an anaerobic lagoon and the Rotating Biological Contactor (RBC).

PROJECT OBJECTIVES

The objectives of this project were as follows:

1. To demonstrate the technical and economic feasibility of using the flushing gutter system for removal of manure from swine confinement buildings.
2. To demonstrate the technical feasibility of a Rotating Biological Contactor in treating the overflow from an anaerobic lagoon receiving liquid swine manure. The goal was to produce an aerobic effluent suitable for reuse as a flushing medium.
3. To demonstrate the technical feasibility of using a surface aerator in treating the overflow from an anaerobic lagoon receiving liquid swine manure and a surface aerator receiving fresh swine manure. In each case, the goal was to produce an effluent suitable for reuse as a flushing medium.
4. To determine operational problems and management skills required for the three swine manure treatment schemes listed above.

SECTION IV

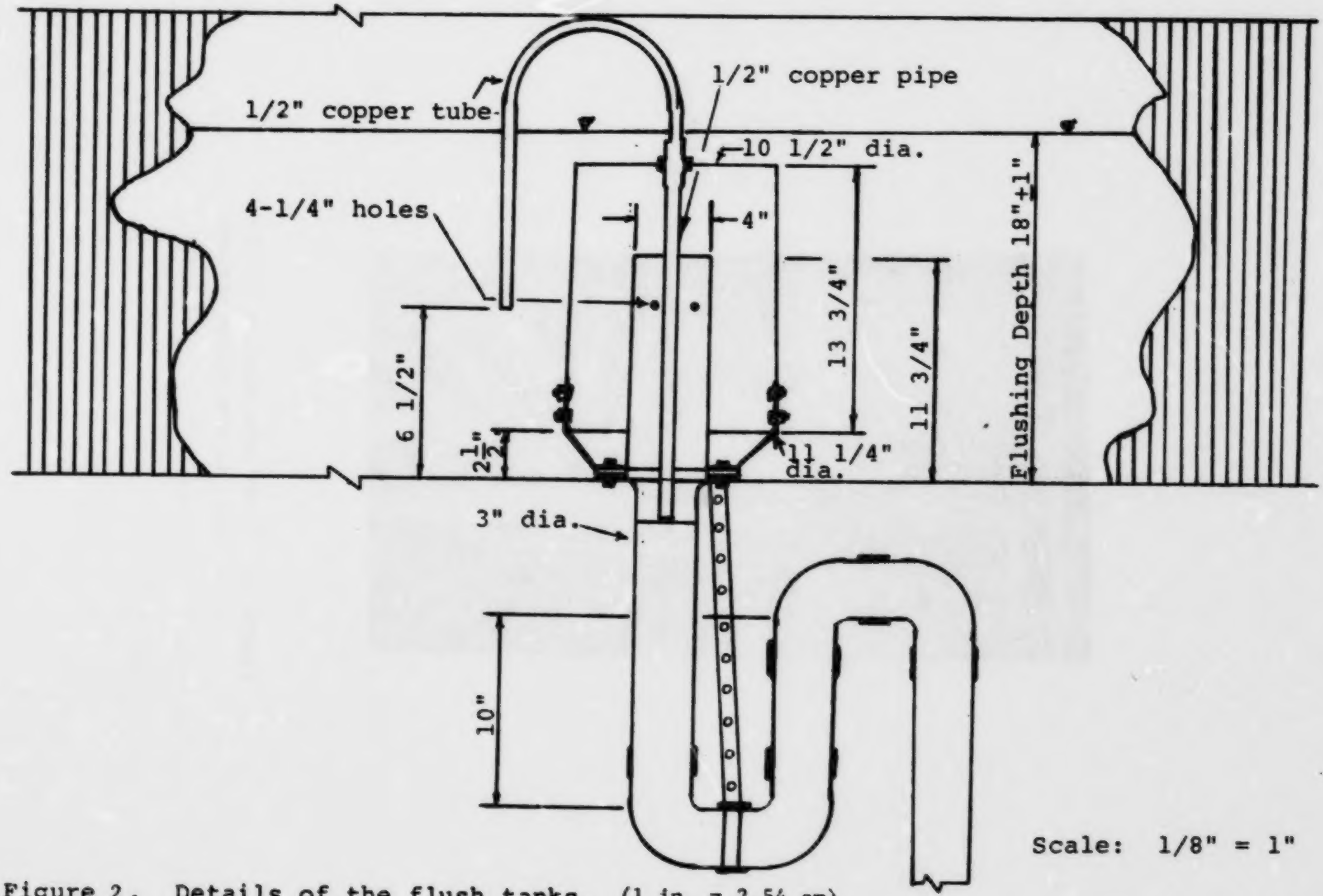
DESCRIPTIONS OF SYSTEMS

Flushing gutters were included in all eight buildings as the only means of manure removal. Effluent from the treatment systems was pumped into flush tanks at the upper end of the buildings. The flush tanks (Figures 2 and 3) were fabricated from 875-1,galvanized steel stock tanks equipped with an automatic dosing siphon. The concept of the dosing siphon is similar to that historically used in sewage treatment plants. Design changes were made which resulted in a device more suitable for the handling of treated livestock wastewater.[13]

Treated effluent was pumped into the tanks continuously. When the water reached a level 45 cm above the tank bottom a siphon was formed discharging the tank contents in one minute. The frequency of flushing was controlled by how fast the tank was filled. This is all accomplished with no moving parts.

AERATION BASIN SYSTEM

The flow scheme for the aeration basin system is shown in Figure 4. This system was designed to serve two farrowing buildings. Five hundred seventy liters of treated effluent were discharged into the flushing gutters at half hour intervals from flush tanks located at the west end of the buildings. The water running down the gutter with the urine and feces from the building flowed into a 15-cm plastic sewer drain pipe. A grate with 5-cm spacing covered the sewer pipe inlet to prevent large objects or baby pigs from entering the sewer line. The sewer line carried the farrowing house effluent by gravity into a 12-m diameter by 3 m deep aeration basin. The manure was treated by an extended aeration basin process. Effluent from the aeration basin was pumped back into the flush tanks by 3/4-hp electric centrifugal pumps. A 15-cm plastic sewer and drain pipe were connected to the anaerobic lagoon to provide storage of excess water. The pipe was so constructed that water


1/2" copper tube
1/2" copper pipe
10 1/2" dia.
4-1/4" holes
4"
13 3/4"
11 3/4"
Flushing Depth 18"±1"
6 1/2"
$2\frac{1}{2}$"
11 1/4" dia.
3" dia.
10"

Scale: 1/8" = 1"

Figure 2. Details of the flush tanks. (1 in. = 2.54 cm)

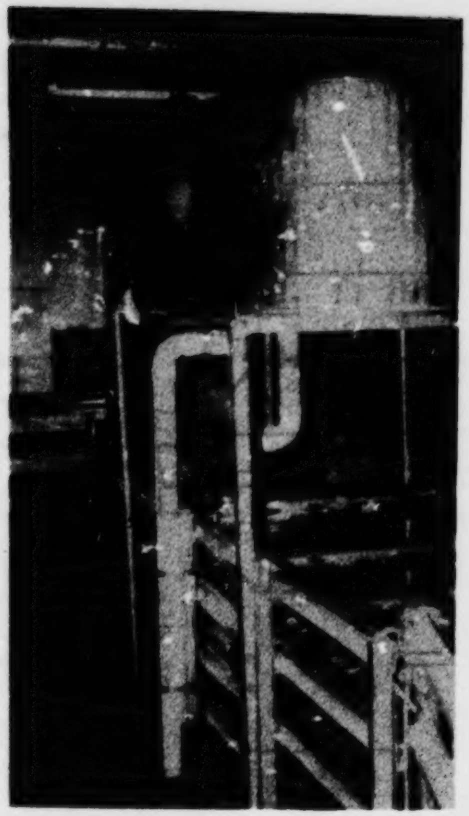


Figure 3. Flush tank similar to the ones in the three systems.

would flow through this pipe when either the lagoon or the aeration basin water surface reached an elevation 1.2 m below the top of the aeration basin. Excess water was irrigated by portable irrigation equipment from the anaerobic lagoon to adjacent cropland.

Design details of the farrowing buildings, each housing 14 sows and litters, included in the aeration basin system are shown in Figure 4 and Table 2.

The nursing area was equipped with a rubber pad to protect baby pigs against abrasions from the concrete floors. A partition was placed on the nursing area side of the gutter 2-5 days before the sow was due to farrow to prevent new-born pigs from getting into the gutter. This partition was removed after the baby pigs were 3-5 days old. The manure was removed from the pen manually while the partition was in place. The creep areas were equipped with electric heat lamps for temperature control. Tempered air was directed to the sows by flexible metal tubing for sow comfort. Suck-type waterers were located near the flushing gutter. The sows were floor fed pelleted feed by hand. The pens had a 5-percent slope toward the gutter which was 6 cm deep, 0.61 m wide, and had a 0.4-percent slope.

The aeration basin (Figure 5) was a 12-m diameter by 3 m deep pit constructed of 15-cm cast concrete walls with an earth bottom. A 5-hp Keene floating surface aerator mixed and aerated the wastewater. Since the effluent was used for gutter cleaning and returned to the aeration basin, it was decided to operate it as an extended aeration unit.

The inlet pipe for the 3/4 hp centrifugal pump consisted of 6-cm flexible plastic pipe which extended into the aeration basin. The inlet end of this pipe was covered with a 1-cm wire mesh screen. A frost-proof water hydrant was located at the flush tank to adjust flow rate. A 2-cm garden hose carried the effluent from the hydrant to the flush tank.

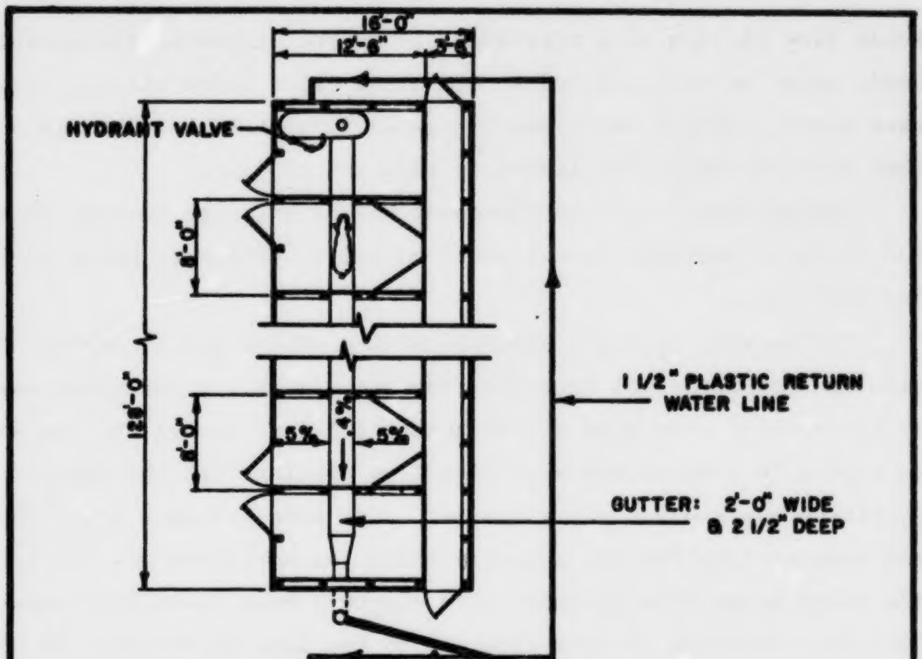

16'-0"
12'-6"
3'-6"
HYDRANT VALVE
8'-0"
128'-0"
8'-0"
5%
4%
5%
1 1/2" PLASTIC RETURN WATER LINE
GUTTER: 2'-0" WIDE & 2 1/2" DEEP
128'-0"
6" PLASTIC SEWER & DRAIN PIPE
40' DIA. X 10' DEEP AERATION BASIN
PUMP
PUMP PIT
2" PLASTIC FLEXIBLE PIPE
1/2" WIRE MESH SCREEN
6" PLASTIC SEWER & DRAIN PIPE
50'X100' ANAEROBIC LAGOON
DRAWING IS NOT TO SCALE

Figure 4. Details of the aeration basin system. (1 in. = 2.54 cm)

Table 2. DETAILS OF THE AERATION BASIN SYSTEM

Item	Aeration basin system
Type	Farrowing
No. buildings	2
Hogs per building	14[a]
Building dimensions (m)	5 x 39
Pens per building	14
Pen size (m)	2.5 x 3.7
Pen slope	5 percent
Gutter width[b] (m)	0.61
Gutter slope	0.4 percent
Aeration basin	
diameter (m)	12
depth (m)	3
hydraulic detention time at 2300 l per hr flowrate	80-160 hours
wall thickness (cm)	15
floating aerator size	5 hp
material	Reinforced concrete

Notes: [a] Sows and litters.
[b] All gutters 7 cm deep.

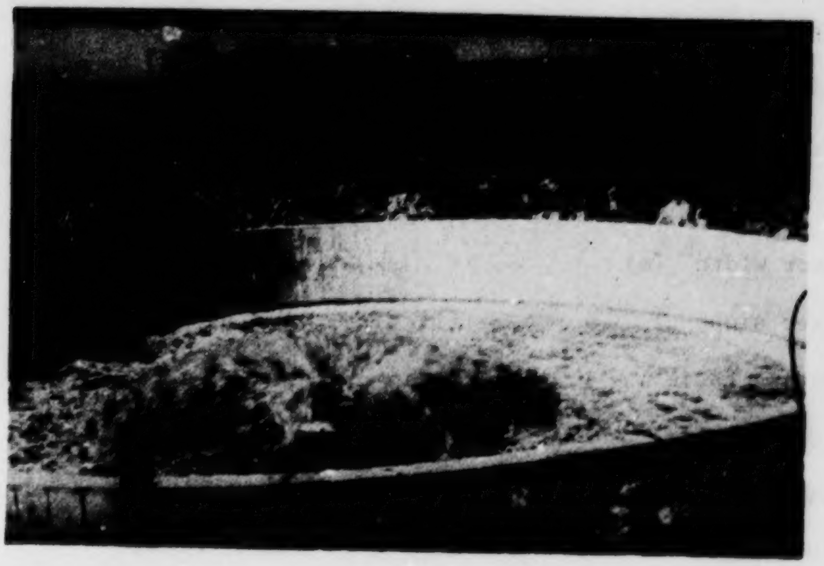


Figure 5. The 12-m Aeration Basin

LAGOON-AERATION BASIN SYSTEM

The flow scheme for the lagoon-aeration basin system is shown in Figure 6. Manure from two farrowing buildings, each housing 28 sows and litters, was discharged by gravity to an anaerobic lagoon. The lagoon effluent flowed through 15-cm plastic drain pipe into a 6-m diameter by 3 m deep aeration basin.

Aeration basin effluent was returned to the flush tanks in each of the farrowing buildings with equipment similar to that in the aeration basin system. Excess water from the lagoon was applied to adjacent cropland by portable irrigation equipment.

Design details of the farrowing buildings and associated waste treatment facilities are shown in Figure 6 and Table 3. These buildings were similar to the farrowing buildings described previously. Each building housed 28 sows and litters, however. The farrowing pens were longer and narrower. Only one creep area was provided. Trough waterers with nose activated valves provided water for the sows.

The lagoon was the primary treatment device in this system. Its function was to decompose and liquify the manure. The main purpose of the aeration basin (Figure 7) was to remove the anaerobic odor from the lagoon effluent before it was returned to the farrowing buildings.

ROTATING BIOLOGICAL CONTACTOR SYSTEM

The flow scheme for the RBC system is shown in Figure 8. Flushing gutters along the wall moved manure from the finishing buildings to an anaerobic lagoon. The anaerobic lagoon effluent then flowed into a wet well inside the RBC building. A sump pump delivered lagoon effluent to the RBC. Centrifugal pumps returned the RBC effluent to the flush tanks located at the head end of each finishing building.

Details of the finishing buildings and anaerobic lagoon are shown in Figure 8 and Table 4. The finishing buildings were designed to be compatible with swine genetic studies. The two buildings with the smaller pens were designed to house one litter in each pen. Each building was designed for up to 160 hogs. The buildings with the larger pens were

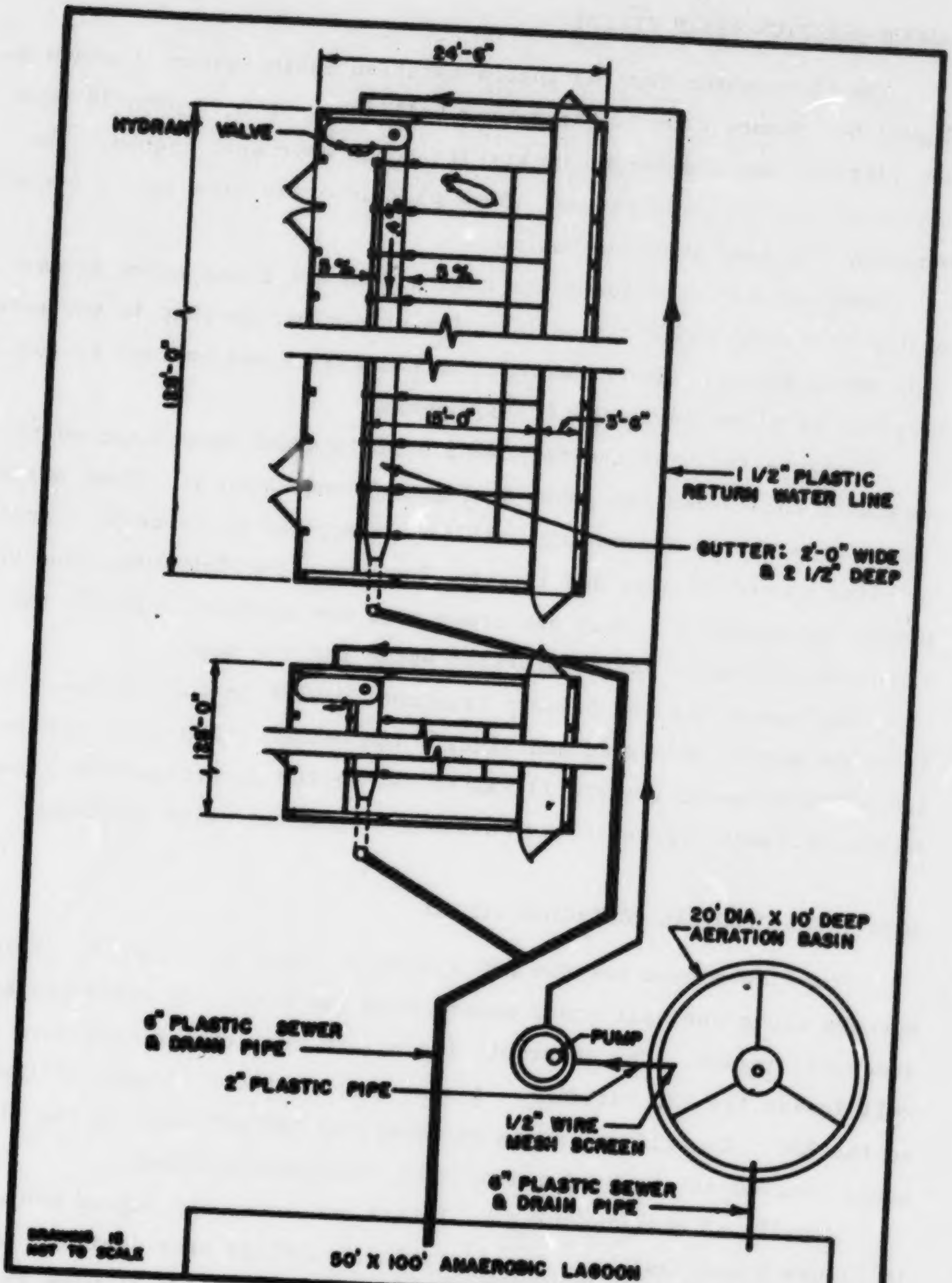

24'-6"
HYDRANT VALVE
5%
5%
100'-0"
15'-0"
3'-6"
1 1/2" PLASTIC RETURN WATER LINE
GUTTER: 2'-0" WIDE & 2 1/2" DEEP
100'-0"
20' DIA. X 10' DEEP AERATION BASIN
6" PLASTIC SEWER & DRAIN PIPE
PUMP
2" PLASTIC PIPE
1/2" WIRE MESH SCREEN
6" PLASTIC SEWER & DRAIN PIPE
DRAWING IS NOT TO SCALE
50' X 100' ANAEROBIC LAGOON

Figure 6. Details of the lagoon aeration basin system.
(1 in. = 2.54 cm)

Table 3. DETAILS OF THE LAGOON AERATION BASIN SYSTEM

Item	Aeration basin system
Type	Farrowing
No. buildings	2
Building dimensions (m)	7.3 x 39
Pens per building	28
Pen size (m)	2.4 x 4.9
Pen slope	5 percent
Gutter width[a] (m)	0.61
Aeration basin	
diameter (m)	6
depth (m)	3
wall thickness (cm)	15
material	Reinforced concrete
hydraulic detention time at 2300 l per hr flow rate	20-40 hrs.
Lagoon	
depth (m)	4.3
length (m)	30
width (m)	15
hydraulic detention time at 2300 l per hr flow rate	10-15 days
design loading rate	80 g VS/m^3-day

Notes: [a]All gutters 7 cm deep.

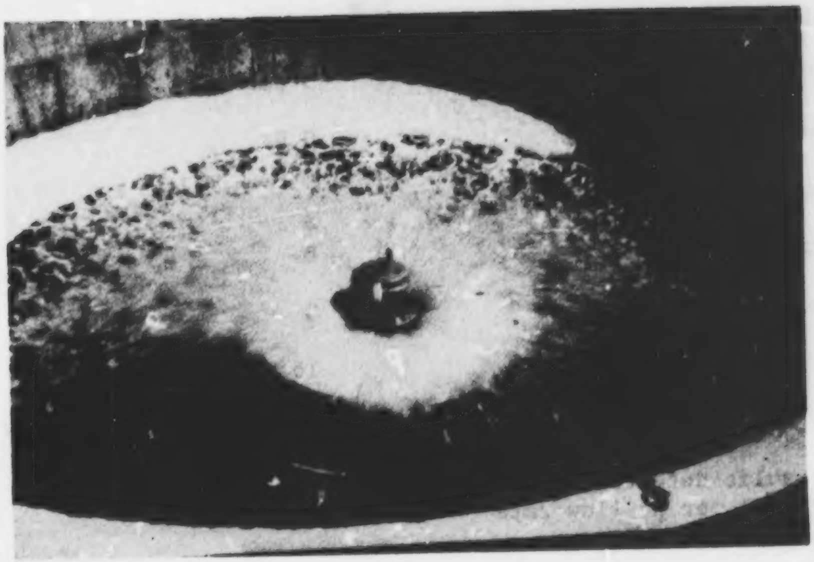


Figure 7. The 6-m aeration basin.

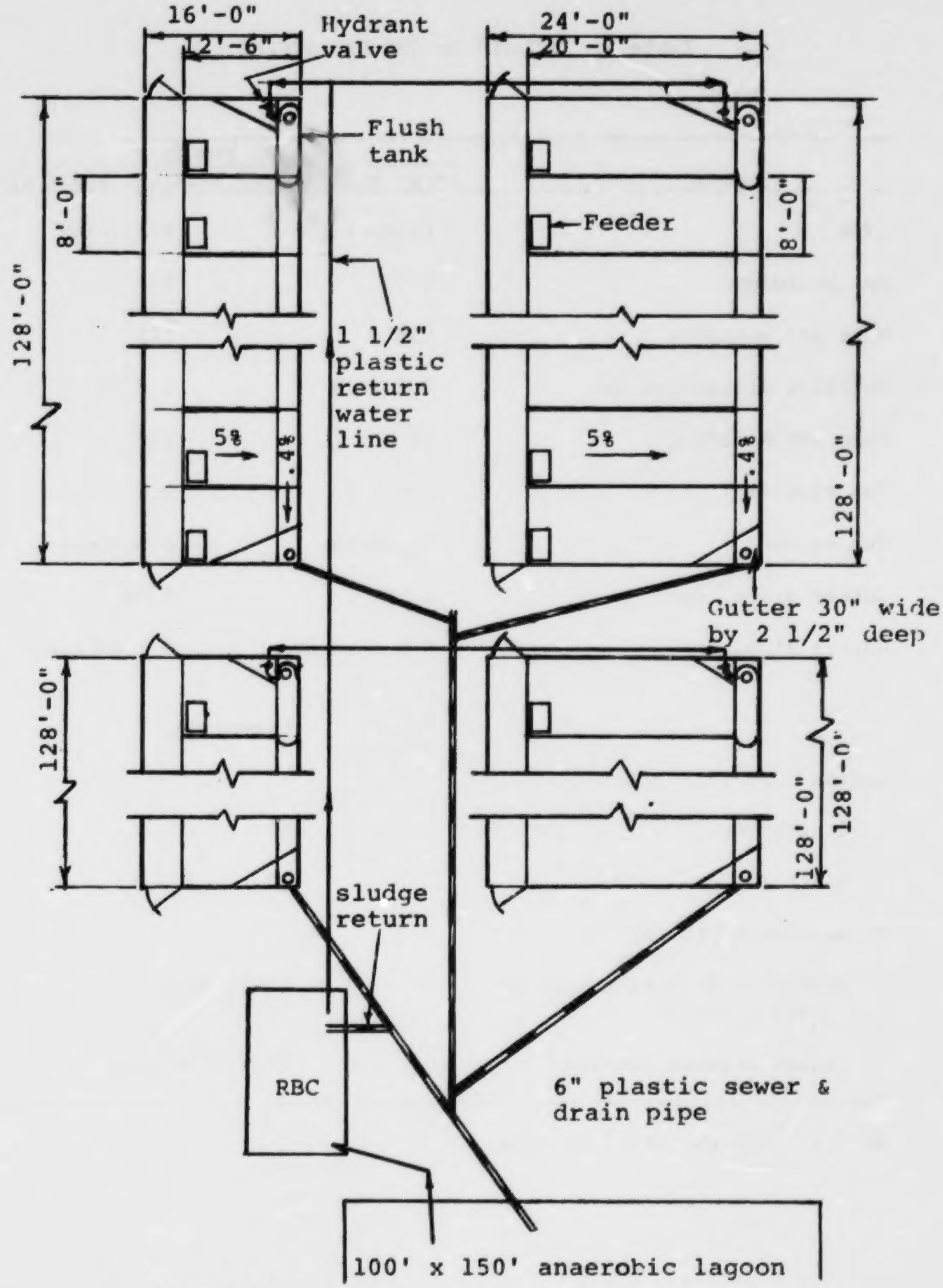

16'-0"
12'-6"
Hydrant valve
24'-0"
20'-0"
Flush tank
8'-0"
Feeder
8'-0"
128'-0"
1 1/2" plastic return water line
5%
.4%
5%
.4%
128'-0"
Gutter 30" wide by 2 1/2" deep
128'-0"
128'-0"
128'-0"
sludge return
RBC
6" plastic sewer & drain pipe
100' x 150' anaerobic lagoon

Figure 8. Details of the RBC system.
(1 ft = 0.3048 meters)

Table 4. DETAILS OF THE RBC SYSTEM

Item	RBC system	
	Large building	Smaller buildings
Type	Finishing	Finishing
No. buildings	2	2
Hogs per building	235	115
Building dimensions (m)	7.3 x 39	5 x 39
Pens per building	16	16
Pen size (m)	2.4 x 6	2.4 x 3.7
Pen slope	5 percent	5 percent
Gutter width[a] (m)	0.76	0.76
Gutter slope	0.4 percent	0.4 percent
	Dimensions	
Lagoon		
length (m)	45	
width (m)	30	
maximum depth (m)	4.3	
hydraulic detention time at 4600 l per hr	15-20 days	
design organic loading	80 g VS/m^3-day	

Notes: [a] All gutters 7 cm deep.

designed to house two litters in each pen for a total capacity of 320 hogs per building.

Two gas-fired unit heaters in each building provided heat in cold weather. Exhaust fans provided winter ventilation. Doors along both sides of the buildings could be opened for summer ventilation.

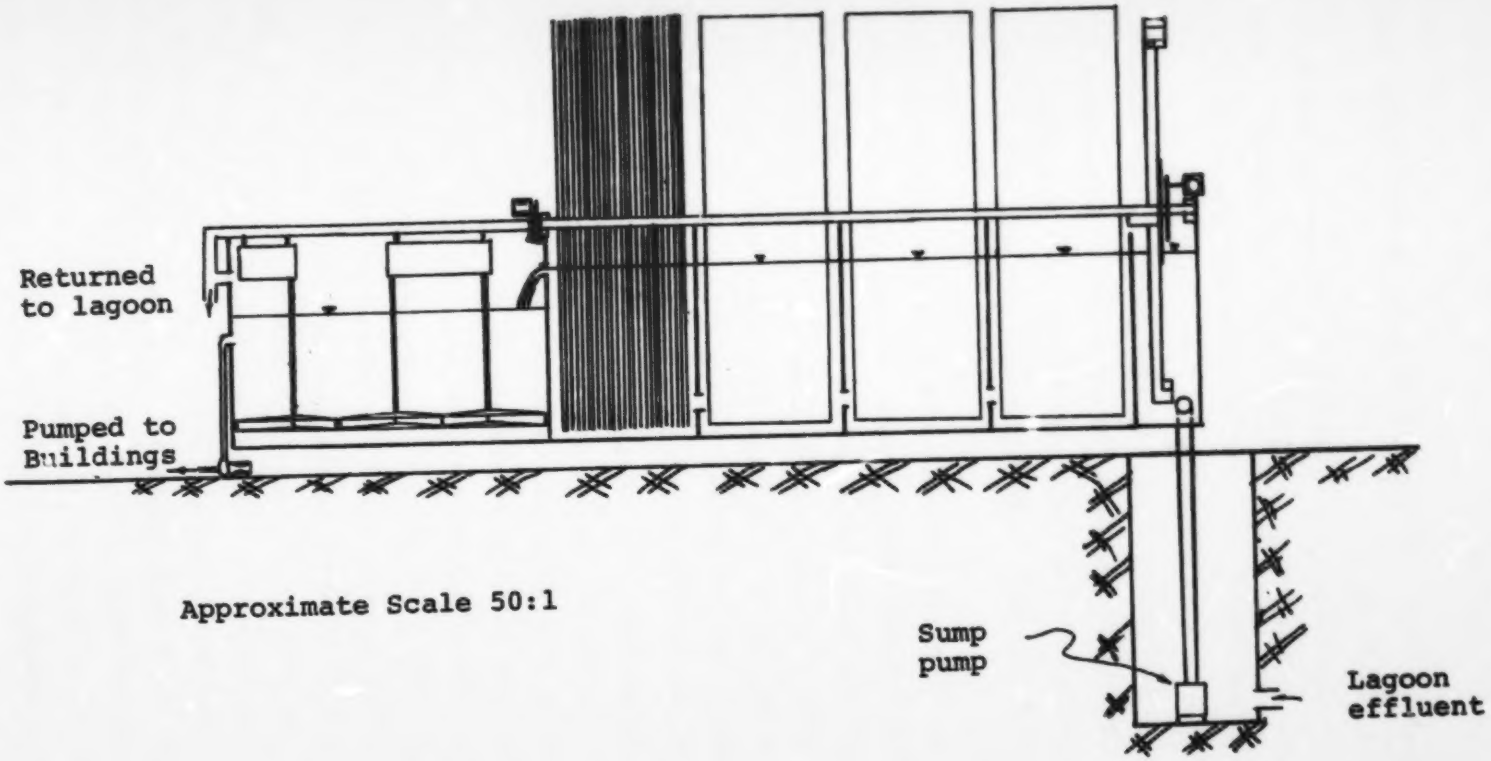
The pens were separated by 1-m high, 15-cm thick concrete walls except in the gutter area. Hultgren[22] found that hogs defecated in areas where they could socialize across a fence. Therefore, to help stimulate the hogs to use the gutter a rod fence was placed in the gutter portion of the wall, allowing visual contact between animals in adjacent pens.

Suck-type waterers were placed in each pen near the gutter. The hogs were fed with self-feeders. Pen slope, gutter slope, and gutter cross section were similar to the other two systems except that 0.76 m wide gutters were used. Liquid wastes from the four buildings flow to an anaerobic lagoon 45 m long, 30 m wide, and 4.3 m deep at maximum water level. At the maximum design flow rate, the lagoon provides liquid hydraulic detention time of 15 to 20 days but a longer solids detention. Lagoon supernatant flows by gravity to a wet-well in the RBC house.

The details of the RBC are shown in Figure 9 and Table 5. The RBC consisted of four sections: influent delivery system, disk section, clarifier, and effluent return system.

The influent delivery system consists of a sump pump that delivers lagoon effluent from the concrete wet-well into the RBC inlet tank. Steel buckets mounted on a 10-cm channel connected to the disk shaft deliver lagoon effluent to the disk section.

In the disk section 104, 3-m diameter by 1-cm thick compressed polystyrene disks were mounted on a common shaft spaced 4 cm apart. The shaft was mounted on the centerline of a 3.1-m diameter horizontal drum. The disks were immersed in the waste water to a level about 15 cm below the shaft. The upper portion of the disks were exposed to the air. The disk section was divided by a steel wall between each of the four compartments. Water flowed from one compartment to anothe


Returned
to lagoon
Pumped to
Buildings
Sump
pump
Lagoon
effluent

Approximate Scale 50:1

Figure 9. Details of the RBC.

Table 5. DETAILS OF THE RBC

Components	Dimensions
Storage Well	
diameter	3 m
length	40 cm
operating water volume	1.1 m^3
Disk chamber	
diameter	3 m
overall length	4 m
total volume	10.1 m^3
net water volume (clean disks)	7.3 m^3
net water volume (0.28 cm slime growth on disks)	5.7 m^3
net water volume (0.65 cm slime growth on disks)	4.0 m^3
disk diameter	3 m
disk thickness	1 cm
disk spacing	4 cm
submerged disk area	2.5 m^2
hydraulic detention time at 38 l per min flow rate	2.1 hr
Clarifier	
volume with water at midpoint of disk chamber outlet	6.1 m^3
volume with water level 8 cm above recycle pipe inlet	3.6 m^3

through 10-cm holes in the steel dividers. The disks and the feed buckets were rotated from 2 to 4 rpm by a one hp electric motor. The hydraulic detention time in the disk section was 2.1 hrs. with a 38-1 per minute flow rate.

Microscopic examination showed that a biological lawn, which consisted of filamentous slime and bacteria, developed on the disks. As the disks rotated through the water, organic material was attached to and/or ingested by the organisms. Oxygen was supplied to the organisms as the disks rotated into the air. The organisms were then able to metabolize the material aerobically. The biological lawn continued to grow and periodically sloughed off. The rotation of the disks kept the sloughed material in suspension until it reached the clarifier. Solids settled in the clarifier where a scraper rotated through the clarifier at about two revolutions per hour. The sludge flowed by gravity to the anaerobic lagoon for further decomposition. Two 3/4-hp centrifugal pumps returned effluent from the clarifier to the finishing buildings.

SECTION V

RESULTS AND DISCUSSION
JULY 1971 THROUGH MAY 1972

AERATION BASIN SYSTEM

Historical Account of Operation

The 5-hp aerator was installed and began operation July 22, 1971. One farrowing cycle had been completed before the aerator was installed. Fresh water was used for gutter cleaning during this time. Since the material in the aeration basin had begun anaerobic decomposition, a slight odor was apparent when aeration began. A small amount of lightweight, light brown foam about 0.3 m wide and 5 to 8 cm thick developed around the periphery of the basin surface. A brown floc of aerobic organisms had developed in the aeration basin by the end of July. This floc had a slightly earthy odor and settled readily when the aerator was turned off.

The flow rate of the effluent returned to each of the flush tanks was reduced from 19 l per min to 10 l per min on July 29 to see how the reduced flushing frequency would affect manure removal from the gutters. During this time, July 29 until August 30, the hydrant valves had to be fully opened every 2 to 3 days to clean material that had settled in the return water lines and had clogged the hydrant valve. Manure solids, hog hairs, grain hulls, and bacteria had to be cleaned from the wire mesh inlet screen once or twice a week. Occasionally muskrats and dead grass got caught in the aerator. These were easily removed by turning the aerator off or floating the aerator to one side and pulling the material from the impeller.

Farrowing sows were put into the buildings on August 12, 1971. The sows defecated and urinated in the rest area and nursing areas as well as in the gutters. The herdsman scraped the manure into the gutters during his routine work in the building. The manure was effectively removed from the flushing gutters when the water ran down the gutters at the one-hour flushing frequency. The sows and baby pigs remained clean and dry. No baby pigs were lost by being carried from pen to pen or into the sewer line by water being flushed down the gutter. The sewer lines in the buildings of all three systems never clogged during the 11-month test period.

Since the hydrants and return lines had to be flushed daily, the hydrants were left fully open after August 30. This resulted in two flushes per hour.

By mid-September, the total solids concentration in the mixed liquor was about 3700 mg/l. Back-flushing the return lines with fresh water to dislodge solids from the hydrant valve and other irregularities in the effluent return systems became necessary about every three days as the total solids concentration increased above 3700 mg/l. During the last two weeks in October the total solids concentration increased to 4500 mg/l and back-flushing became necessary every day.

On November 2, the floating aerators were removed and returned to the manufacturer for modification. The motor mounting bolts of the 3-hp aerator in the lagoon aeration basin system had broken three times. Since the 5-hp motor had the same size and number of mounting bolts, it was also returned. The solids settled readily after the aerator was removed and a clear effluent was returned to the farrowing buildings. No clogging problems occurred after the aerator was removed.

By November 17, the basin contents had gone anaerobic. There was a slight acetic odor within 6 m of the flush tank; however, it did not cause problems within the farrowing building. During this time the water in the flush tank was also covered with a 8-cm layer of light weight brown foam from water splashing into the tank.

The buildings were emptied of sows and litters by November 19. To prevent freezing of the return lines, the treated effluent was returned to the flush tanks until mid-December when the return pump failed.

Sows entered the farrowing buildings again on February 9, 1972. Fresh water was used for gutter cleaning. Although the aerator had been removed, the aeration basin remained free of ice in the center all winter except during one period when the air temperature remained below -12 C. for 2 to 3 days.

Before the floating aerator was reinstalled on March 16, 1972, probing of the bottom revealed that very few solids had accumulated. Since the effluent was about to overtop the basin walls at that time, the storage lagoon was pumped into the RBC lagoon. The water could not be irrigated to land because the soil was still frozen.

By March 20 an aerobic floc had developed in the aeration basin. The floating aerator operated satisfactorily except for intermittent electrical failures caused by the thermal overload opening the circuit. Power and current measurements indicated that more power and current were being used than the motor was rated for. The cause of this has not yet been determined. The aeration basin system did not produce odors considered to be obnoxious throughout the test period.

Water Quality

The aeration basin system received a somewhat variable waste load during the test period due to the farrowing pattern of the station. This variation was anticipated, however, in the design of the system. Measured values of water quality parameter are summarized in Table 6. Estimated removal efficiencies for various parameters are given in Table 7 for the period July 22 to November 2, 1971, when recycling was practiced and the aerator was in operation. This table is based upon the standard manure characteristics[9] and the quantity of material in the basin on November 2, 1971. A detailed tabulation of the water quality data for this system is given in Appendix C.

The constituent removal efficiencies may be somewhat inflated since a portion of the aeration basin effluent may have been discharged into the anaerobic lagoon. The flow between the lagoon and the aeration basin was not measured. These data do indicate, however, that significant reductions in BOD_5, COD, and total and volatile solids have occurred. The phosphate reductions may have been caused by aeration basin effluent running into the lagoon as well as errors in the estimate of phosphate production.

The BOD_5 and COD (Figures 10 and 11) decreased steadily after aerator operation began as the manure that had been added earlier was metabolized. Sows were returned in the farrowing buildings August 12, 1971. After that the BOD and COD increased steadily until November 2, when the aerator was removed.

A sharp drop was noted in the COD after the aerator was removed because the solids settled leaving a clean supernatant. The farrowing buildings were empty after mid-November. A slight increase in BOD_5 and COD was measured as the aeration basin went anaerobic. Apparently as the aerobic

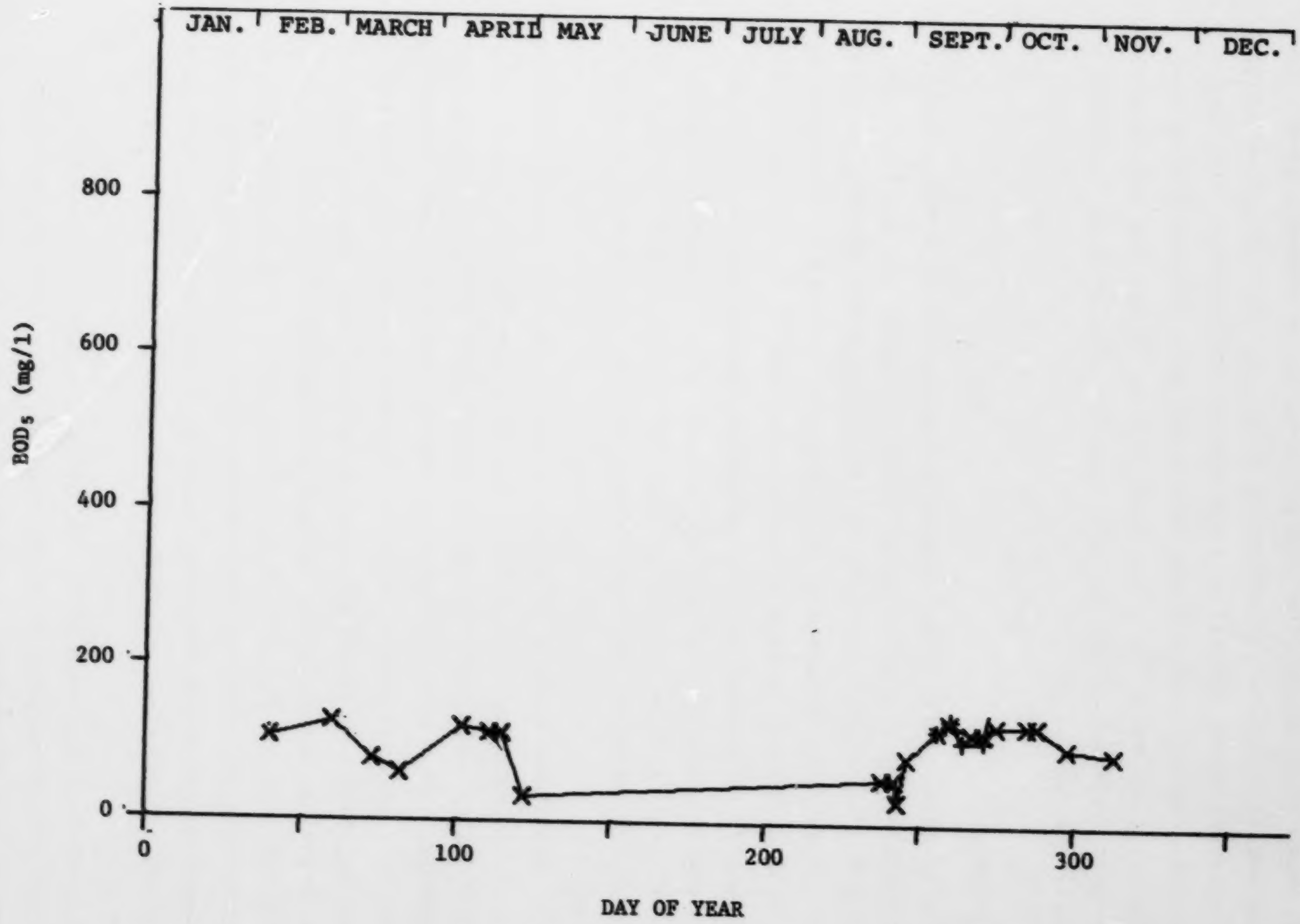


Figure 10. BOD_5 vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

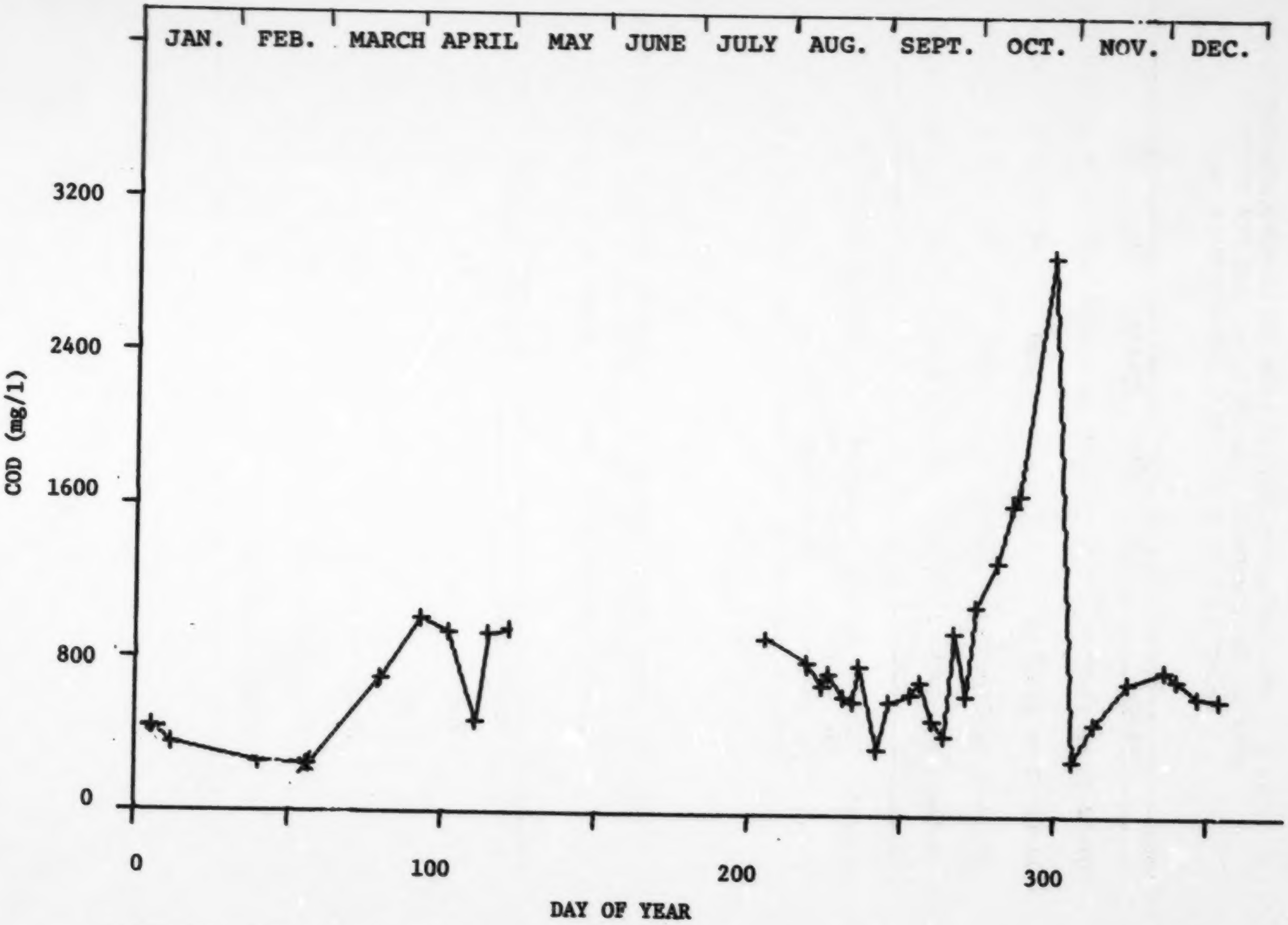


Figure 11. COD vs time for the 12 m aeration basin effluent, August 1971 to May 1972.

Table 6. EFFLUENT WATER QUALITY FROM THE 12-METER AERATION BASIN SERVING TWO FARROWING BUILDINGS, 14 PENS PER BUILDING, AUGUST 1971 TO APRIL 1972, AVERAGE VALUES mg/1.

Period	D.O.	BOD	Solids	PO_4	pH	NH_3-N	NO_3-N
07-22-71 to 11-02-71[a]	8.0	200	3000-6000	150	8.4	2.0	50
11-02-71 to 12-15-71[b]	1.0	300	2700	50	7.6	65.0	0
12-15-71 to 03-16-72[c]	1.0	120	1700	30	7.6	30.0	2
03-16-72 to 05-01-72[d]	7.5	350	2600	60	7.6	20.0	-

Notes: [a] Five hp aerator in operation - effluent recycled.
[b] No aeration - effluent recycled.
[c] No aeration - fresh water flushing.
[d] Five hp aerator in operation - fresh water flushing.

Table 7. CONSTITUENT REMOVAL EFFICIENCY OF THE 12-METER AERATION BASIN SERVING TWO FARROWING BUILDINGS, 14 PENS PER BUILDING, JULY 22 TO NOVEMBER 2, 1971.

Constituent	Percent removal
BOD	97
COD	90
Total solids	75
Volatile solids	87
Total phosphate	40

cells lysed they added organic material back into solution. The BOD_5 and COD were low during the winter months, December through early February, but the BOD and COD began to increase as farrowing sows occupied the building. In mid-March water was transferred from the aeration basin into the RBC lagoon to prevent the basin from overtopping. Rainfall diluted the aeration basin contents causing the BOD_5 and COD to remain nearly constant until the end of the test period.

The total and volatile solids concentration (Figures 12 and 13) followed a pattern similar to that of the BOD and COD. There was no increase in either of these parameters two weeks after the aerators were removed as occurred with the COD.

The total phosphate concentration in the aeration basin remained relatively constant from start-up until mid-August when farrowing sows entered the buildings. After this time the total phosphate increased as manure was added to the system. A maximum of 245 mg/l of phosphate was in the system just before the aerator was removed (Figure 13).

After aerator removal, the phosphate concentration in the settled effluent was only 43 mg/l. The total phosphate remained near or below this level throughout the winter. Since no animals were in the buildings from December through mid-February, when animals entered the buildings, fresh water was used for flushing which diluted the mixture since some of the aeration basin effluent went into the lagoon. After the aerator was installed the total phosphate concentration increased only slightly to 64 mg/l by late April.

Chloride ion concentration was measured to provide an indication of salt build-up within the recirculating system. Figure 14 shows the chloride concentration in the aeration basin effluent versus day of the year. The chloride concentration increased steadily from start up until the last week in September when rainfall diluted the liquid. It then increased until the first week in November when the aerator was removed. At this point the chloride concentration decreased markedly. Apparently the chloride was tied up in the settled cells. During the first week in December, a sharp increase occurred. This coincided with the time the aeration basin went anaerobic. Apparently, the aerobic cells lysed and added chloride ions back into solution. After mid-December the chloride concentration decreased steadily as the temperature decreased. During this time the return pump

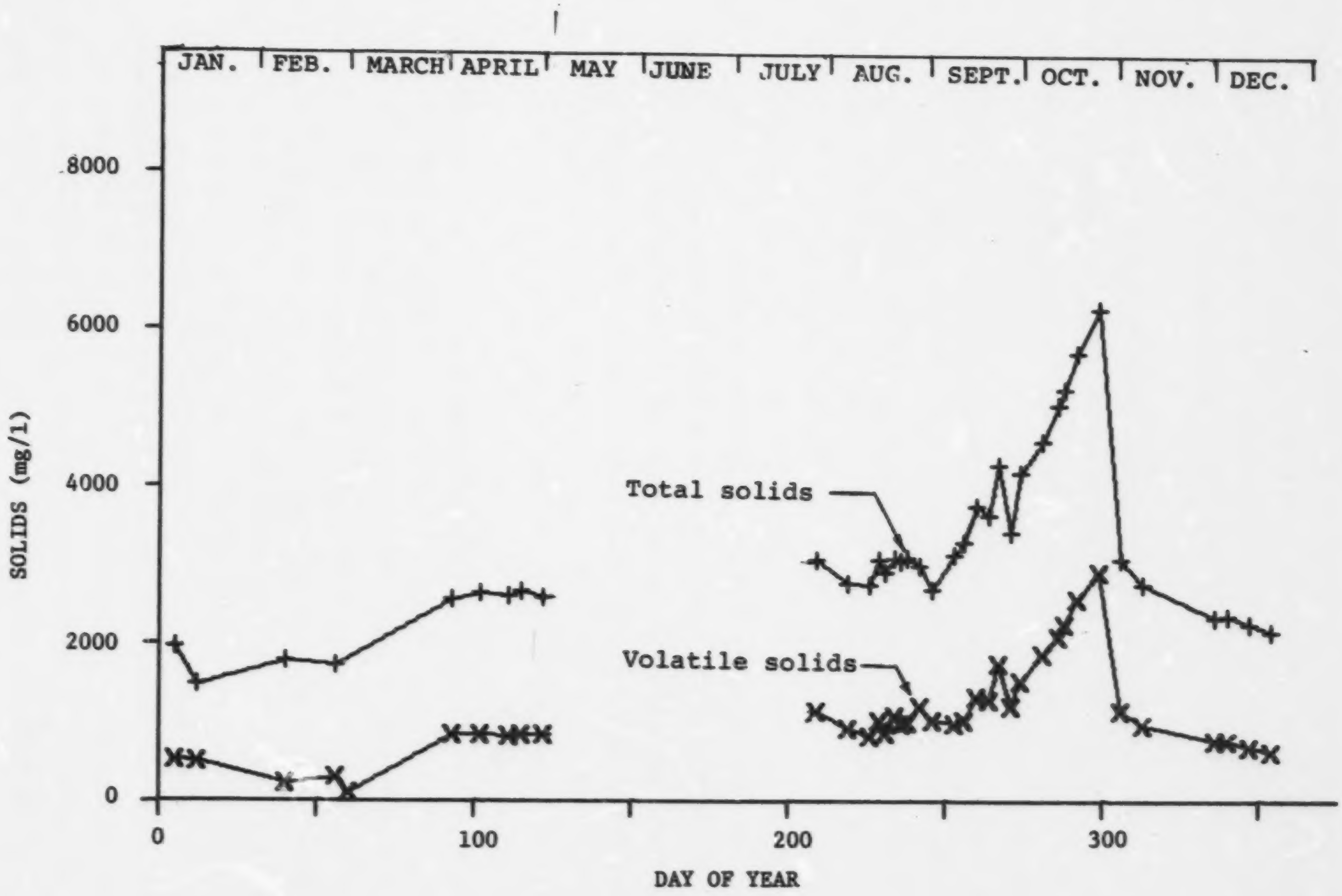


Figure 12. Total and volatile solids vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

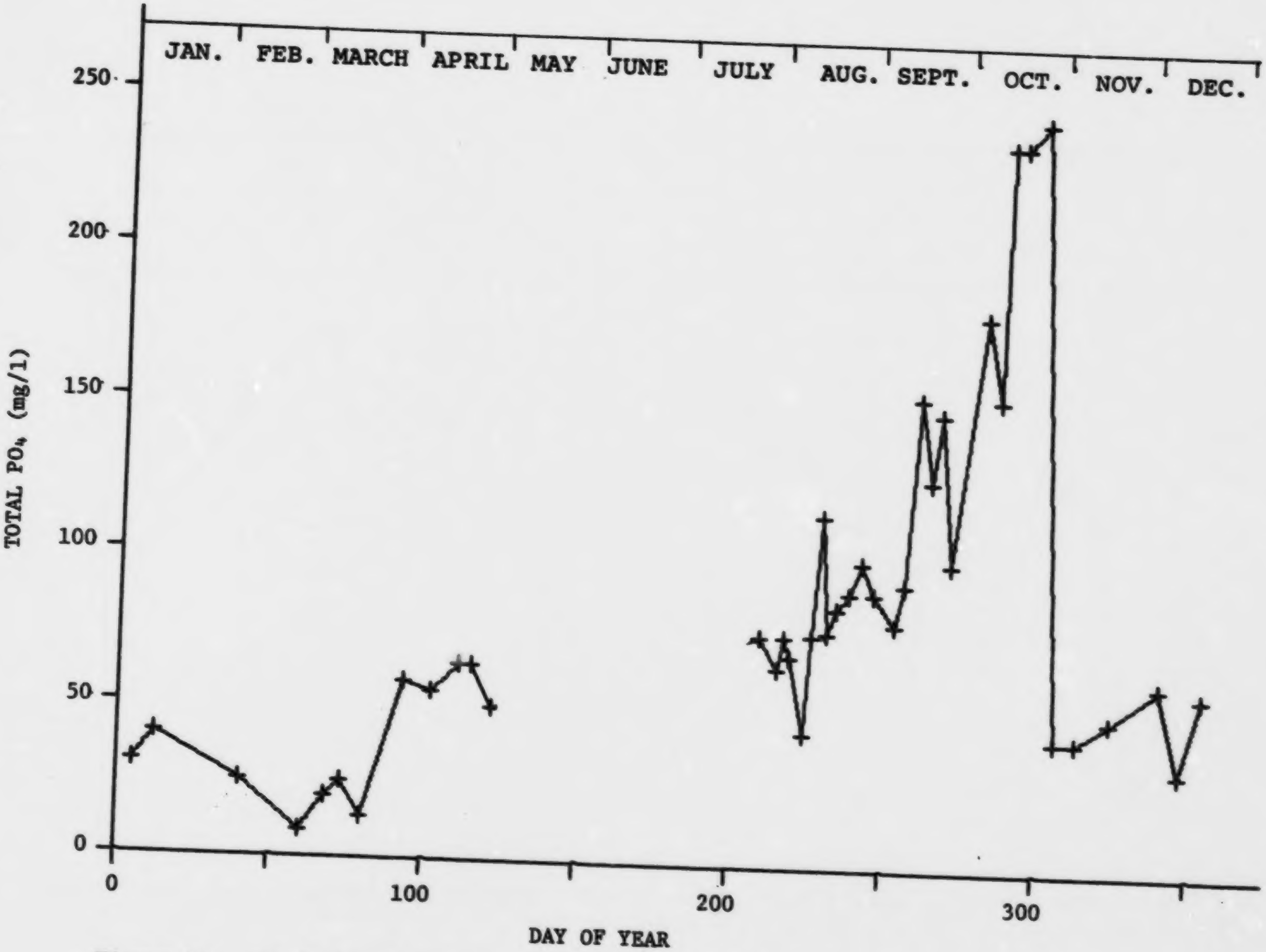


Figure 13. Total phosphate conc. vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

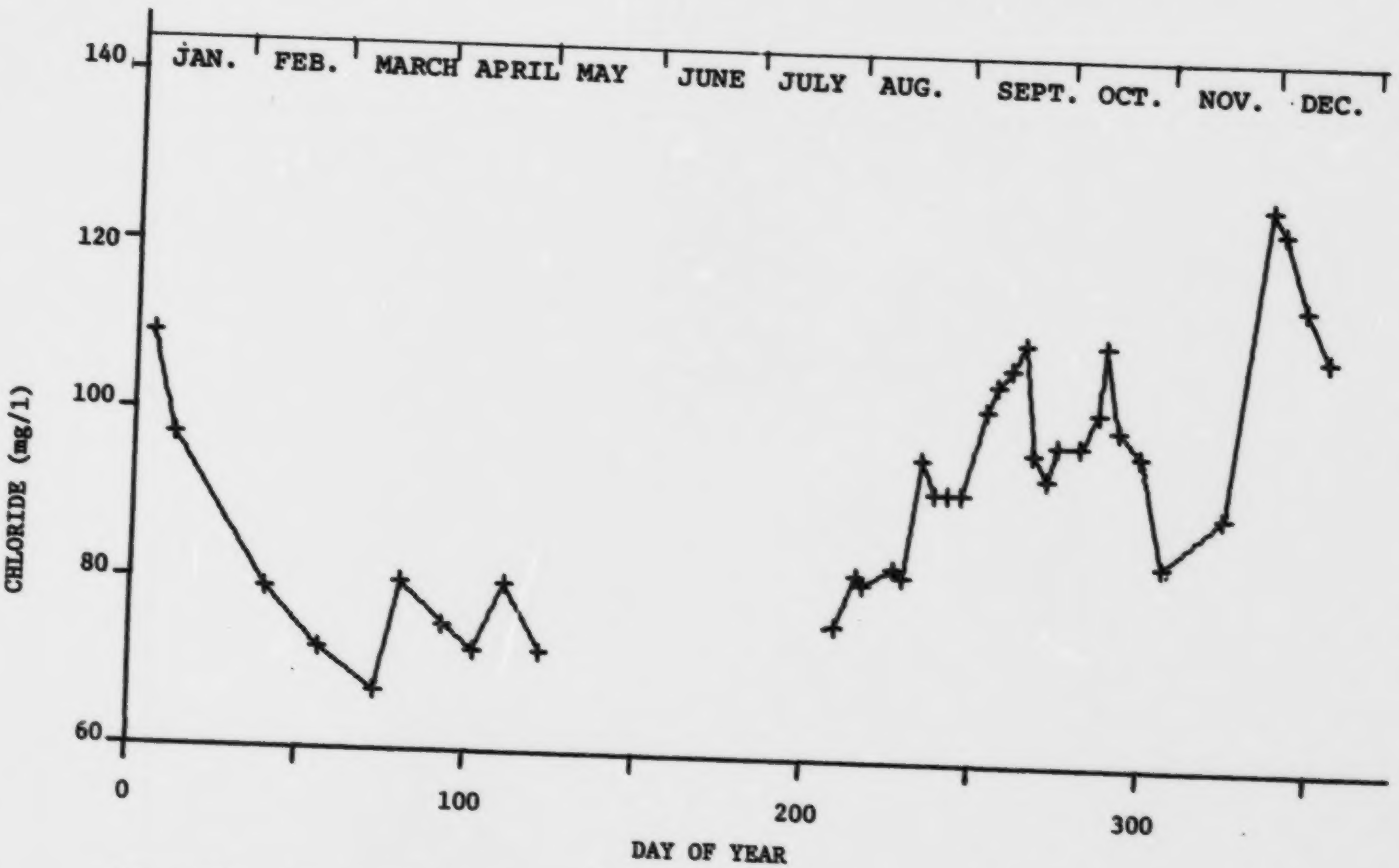


Figure 14. Chloride conc. vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

failed and fresh water was added to the system. During February through May, sows were in the building and added chloride ions but because fresh water was used for flushing, the chloride concentration did not increase as markedly as during July through November. One would expect the chloride concentration in the system to reach an equilibrium concentration as excess effluent is irrigated and some salts are removed.[23] Smith[23] calculated that this equilibrium concentration is not high enough to inhibit bacterial activity.

While the aerator was in operation, from July 22 until November 2, 1971, the dissolved oxygen concentration in the aeration basin was 90-99 percent of saturation (near 8.3 mg/l) (Figure 15). During this same period, the pH ranged from 8.0 to 8.5 (Figure 16). From July 22 until August 5, 1971, the ammonia concentration ranged from 39.0 to 29.4 mg/l (Figure 17).

By August 14 the ammonia concentration had dropped to 3.0 mg/l. The ammonia concentration then remained in the range 0.0 to 7.0 mg/l until November 2, 1971. During this period, the ammonia was converted to nitrate concentration, which ranged from 33 to 143 mg/l. During this time the baby pigs were observed playing in the water and possibly drinking it, but no health problems due to nitrate toxicity were evident.

After the aerator was removed on November 2, 1971 the dissolved oxygen in the basin liquid dropped sharply to near 1.0 mg/l. As anaerobic conditions began to develop, nitrification of ammonia to nitrate no longer occurred. The ammonia concentration increased while some of the nitrate was reduced to N_2 by denitrification. Anaerobic activity generated organic acids as evidenced by a drop in pH from 8.4 to 7.5.

During the winter months November,1971,through February,1972, the dissolved oxygen concentration remained near 1.0 mg/l because of no mixing and a partial ice cover.

Ammonia concentrations decreased markedly after November 20 since the farrowing buildings were vacant and no manure was added to the basin. Some volatilization of ammonia may have occurred or water from the lagoon which had an ammonia concentration from 25-57.5 mg/l may have entered the aeration basin causing some dilution. Nitrate concentrations were near zero from November 2, 1971, until March 13, 1972. The pH remained between 7.5-7.8 from November 2 until February 9. By February 25th, the pH had decreased to 7.0.

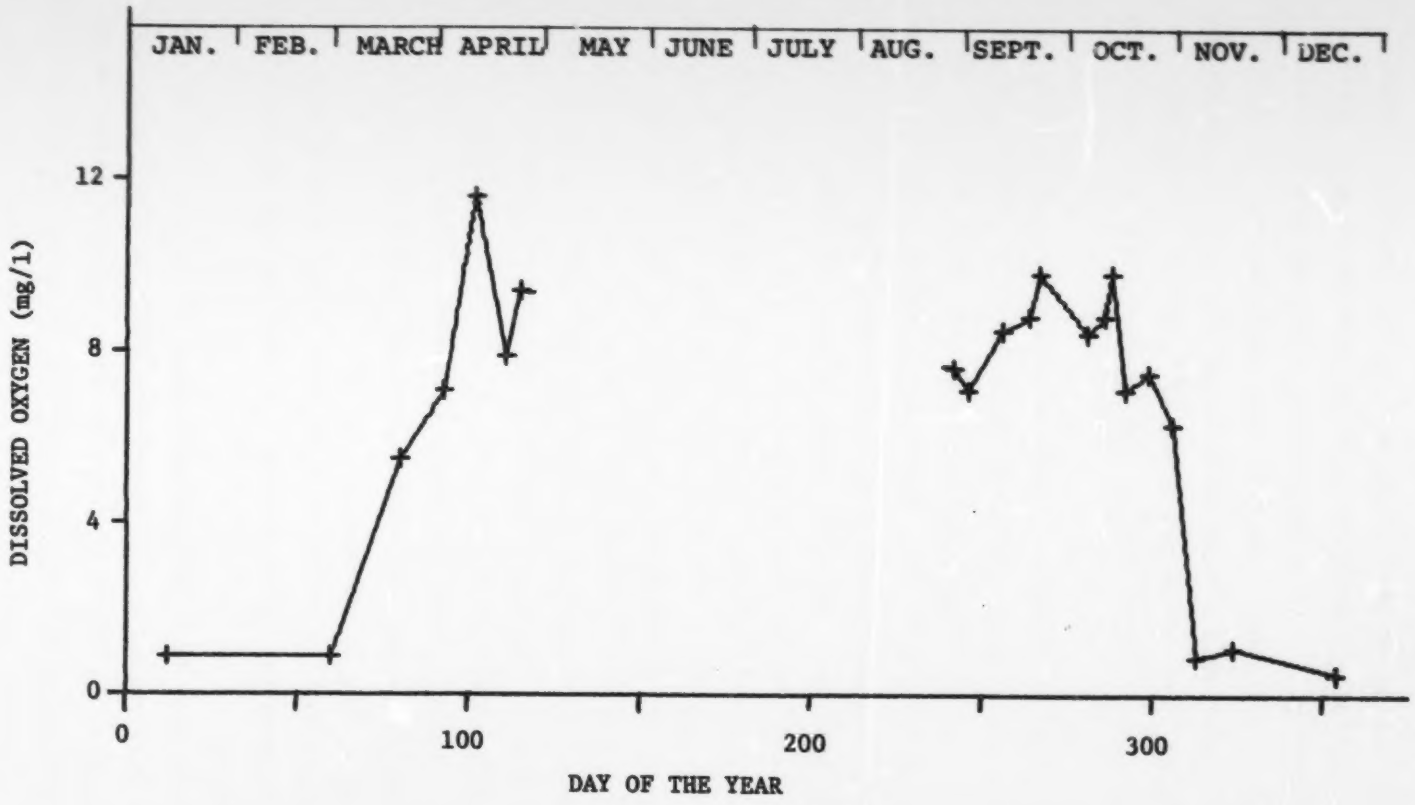


Figure 15. Dissolved oxygen conc. vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

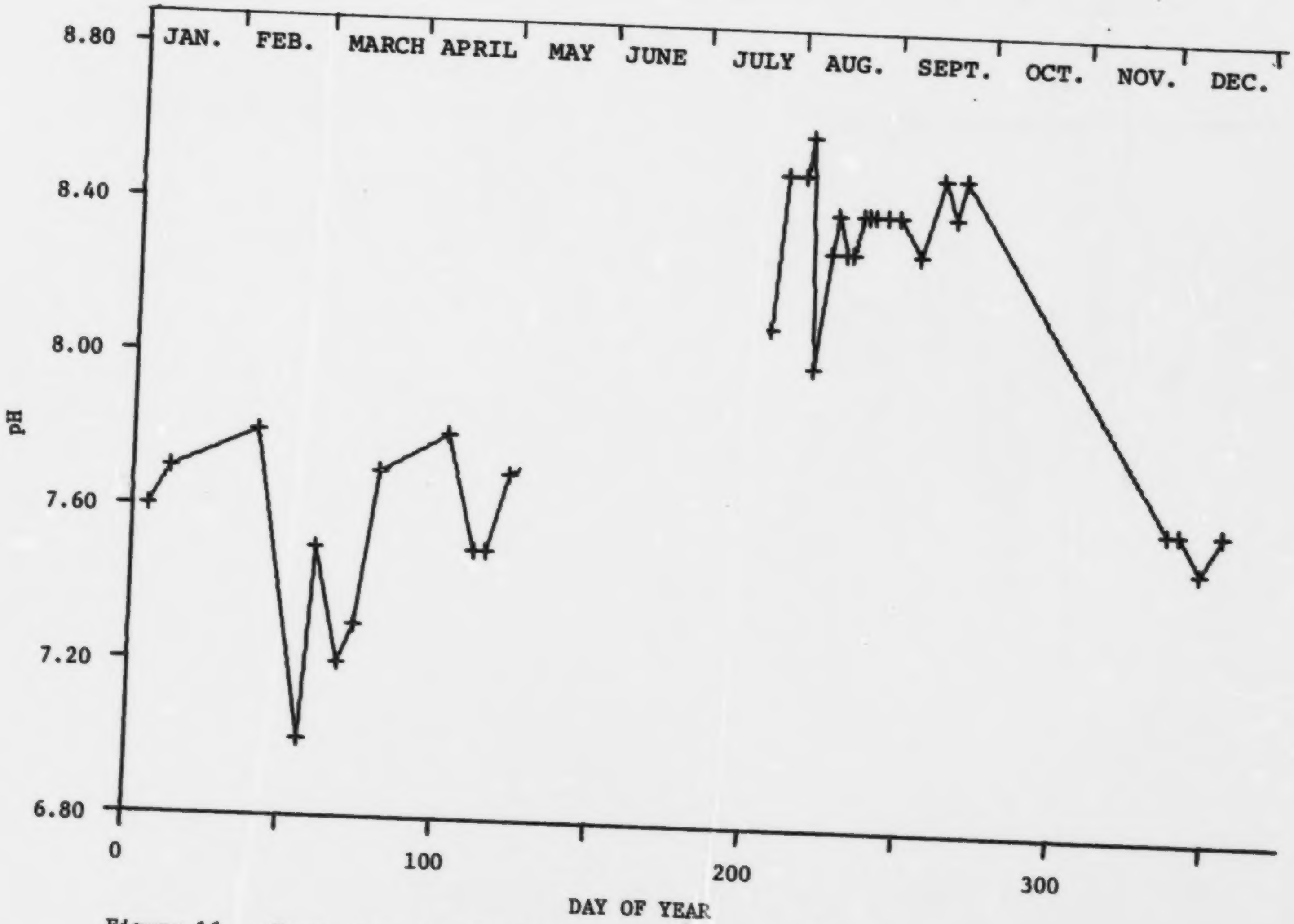


Figure 16. pH vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

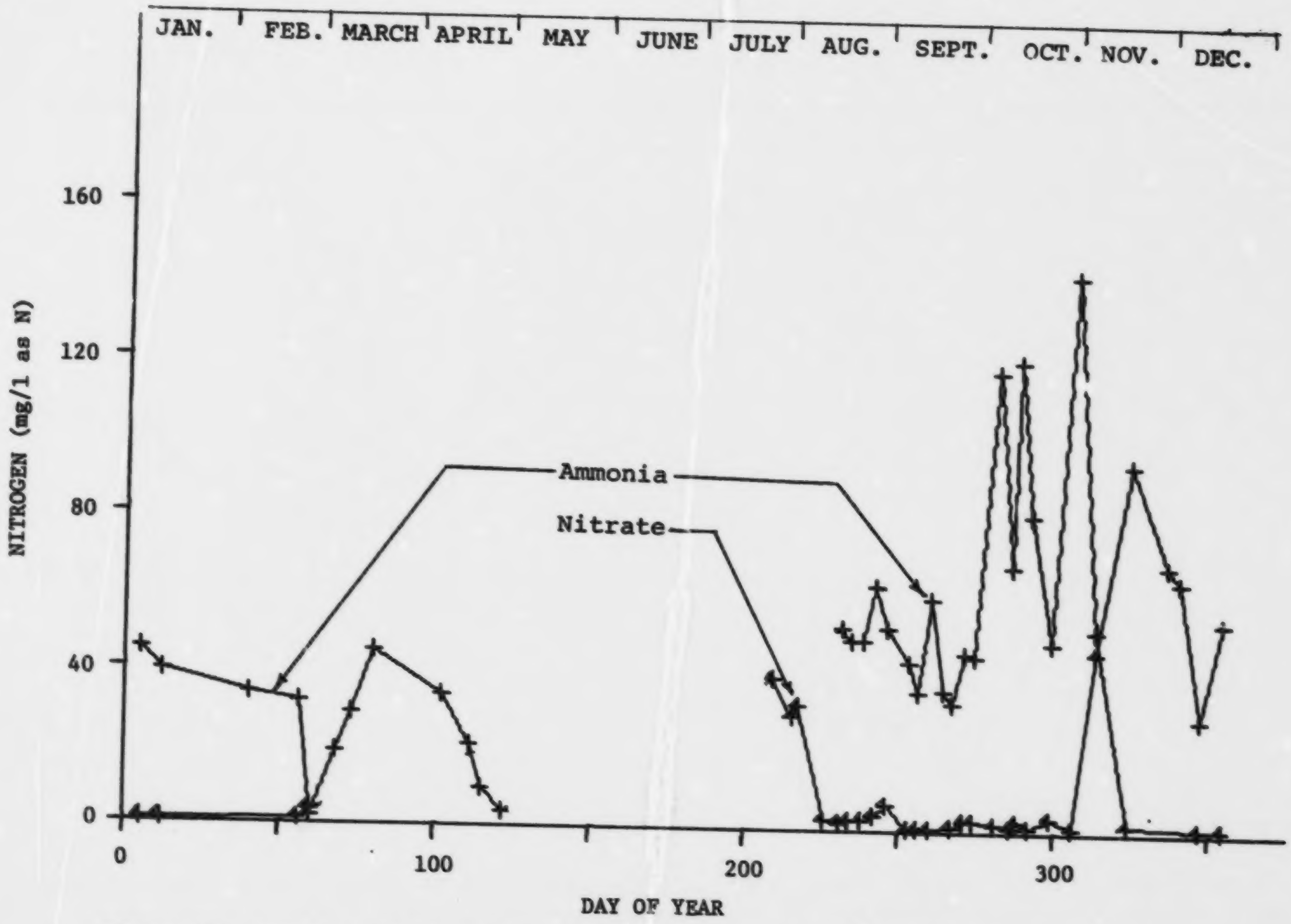


Figure 17. Ammonia and nitrate conc. vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

This may have been caused by bacterial activity produced by warm, fresh water and manure added after animals began occupying the farrowing building on February 9. Acids and CO_2 were probably produced causing a decrease in pH. By April 11, the pH had increased to 7.8 following the ice cover melt and installation of the aerator allowing aerobic conditions to exist. The pH ranged from 7.4 to 7.7 from April 11 until June, 1972.

After installation of the aerator, the dissolved oxygen concentration rose from 5.5 mg/l (40 percent of saturation) on March 20 to near saturation by April 11, where it remained until June.

After March 20, the ammonia concentration showed a gradual decline. Because of analytical difficulties, no nitrate analyses were made. However, one may suspect that nitrification may have occurred as well as some ammonia volatilization.

Organic nitrogen (Figure 18) showed a general increase from July 24 through November 2, 1971, corresponding to the increased solids concentration. After the aerator was removed, the solids settled and the effluent contained less organic nitrogen. When the aerator was reinstalled on March 16, 1972, an increase in organic N occurred since the accumulated manure was mixed with the liquid.

LAGOON-AERATION BASIN SYSTEM

Historical Account of Operation

The three-hp floating surface aerator was installed July 22, 1971. One farrowing cycle had been completed before the aerator had been installed. Fresh water was used to clean the gutter during this time. No odor was noticed from the aeration basin after it began operation. A light, white foam about 0.6-1.0 m high and 0.6 m wide developed around the periphery of the basin liquid surface. The 1-cm wire-mesh screen on the pump inlet pipe had to be cleaned of dead grass and hog hair once or twice each week.

On July 29 the flow rate of the return effluent to the flush tanks was reduced from 18 l per min. to 9 l per min. (1 hour flushing frequency) to see how the reduced flushing frequency affected manure removal from the gutters. During this time, the hydrant valves had to be fully opened every 2-3 days to remove material that had settled in the return lines and clogged the hydrant valve.

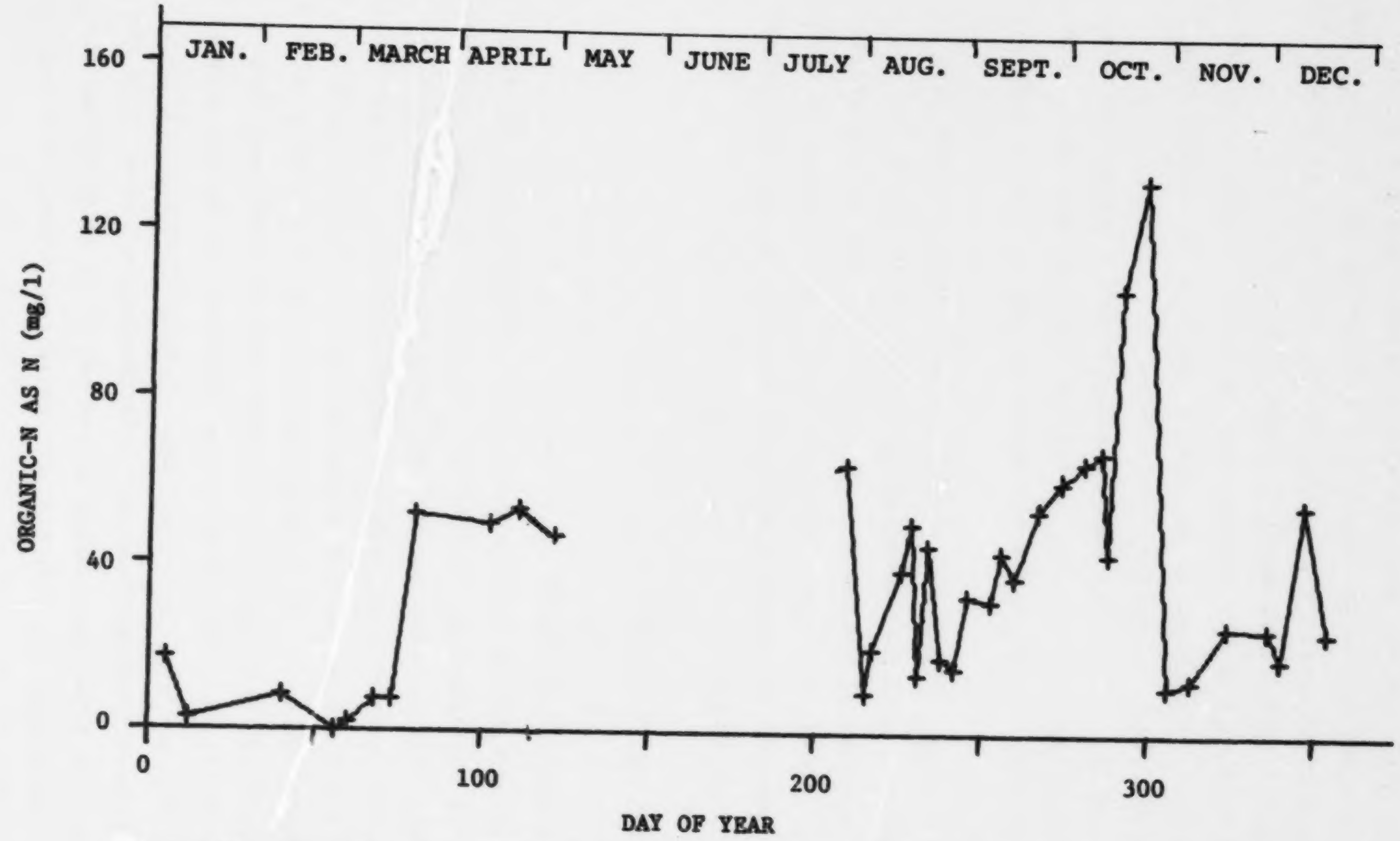


Figure 18. Organic nitrogen conc. vs. time for the 12-m aeration basin effluent, August 1971 to May 1972.

Sows entered the farrowing buildings on August 12, 1971. They did not respond to the flushing gutters as planned primarily because of pen design. The pens were 1.4 m wide (Figure 6). A 450-500 pound sow is sufficiently long that she could not conveniently get the full length of her body in the gutter. A sow would stand with her front feet in the gutter and root in the running water. Her feces and urine were dropped on the pen floor 1-2 m from the gutter resulting in the pens being generally damp and dirty. The sows and baby pigs also were frequently damp and dirty. This required daily manual scraping of manure from the pens into the gutter. This required about 10 minutes per building per day.

Once in the gutter, the manure was efficiently removed from the gutters when the one hour flushing frequency was used. Since return line cleaning was required at the reduced flow rate, the valves were left fully open after August 30, 1971 to avoid having to clean the return lines and valves. After this was done, the only maintenance required was to clean the pump inlet screen and close and open the hydrant valves once or twice each week to be sure the return line was not becoming clogged. Occasionally muskrats, dead grass, or corn leaves got caught in the aerator, but were easily removed.

The aerator was sent back to the manufacturer for modification on November 2, 1971, because of motor mount failure on three prior occasions. Few problems were encountered with returning the effluent to the flush tanks while the aerator was not operating from November 2, 1971, until March 31, 1972. During the winter, an ice cover from 2 to 20 cm thick developed on the aeration basin. The pump inlet pipe operated below the ice cover with no plugging problems. No odors from the return effluent were noticed in the farrowing buildings.

From mid-April until early June there was a slight odor from the anaerobic lagoon as spring overturn occurred and anaerobic activity began to decompose the manure that had accumulated through the winter. The effluent returned to the farrowing building did not cause any odor problem in the building, however. A survey of sludge accumulation on the bottom of the anaerobic lagoon revealed virtually no solids accumulation on the lagoon bottom.

On April 8, irrigation of excess lagoon effluent to adjacent crop land began. No odor was noticed during this operation.

No odors were noticeable from the aeration basin while the aerator was in operation. Apparently the odors, if present, were emitted slowly enough and at low enough concentrations, that no odors were noticed.

Water Quality

Table 8 shows the quantity of BOD_5, COD, total and volatile solids, and phosphate added to the lagoon aeration basin system from start-up on July 22, 1971,until March 16, 1972,when excess water was removed from the system. The table also shows the quantity of these various parameters in the system when excess water was removed as well as the total amount that was actually removed. The BOD_5, COD, and total and volatile solids reduction was quite satisfactory. Only 5, 3, 16, and 4 percent of the BOD, COD, and total and volatile solids respectively that were produced was applied to the land. The remainder was stored in the lagoon or had been metabolized to methane, carbon dioxide, and water. As one would expect, essentially no phosphate was removed in the lagoon.

Because the aeration basin was designed primarily to remove odors from the lagoon before returning effluent to the farrowing houses, no sludge recycling was practiced. Since the hydraulic detention was only around 30 hours, solids buildup was low, and the reductions in BOD_5 and other parameters was insignificant. The reductions in the same parameters for the anaerobic portion are slightly higher than those reported for similar lagoons.[6,23] This is because the system was not continuously fully loaded allowing the bacteria to metabolize the material more completely. Farrowing sows in cycles is quite common in swine production facilities.

The BOD_5, COD, and total and volatile solids concentration (Figures 19, 20, and 21) in the lagoon and the aeration basin showed a general increase as manure was added to the lagoon. After the sows were removed, these parameters showed a sharp decrease as the bacteria metabolized the organic material that had accumulated. This illustrates how quickly anaerobic organisms can metabolize organic material. The COD, total and volatile solids remained relatively constant from December through early March. The BOD_5 showed a steady increase from January through early March. This rise corresponds with sows being in the farrowing buildings from late January through early May.

BOD_5, COD, and total and volatile solids all decreased after mid-March when excess water was being removed and snow melt and rain water diluted the liquid. The farrowing sow population also declined steadily during this time.

Table 8. WASTE TREATMENT PERFORMANCE OF THE LAGOON-AERATION BASIN SYSTEM JULY 22, 1971 TO MARCH 16, 1972 WHEN IRRIGATION BEGAN.

Item	Quantity added[a] by raw manure, kg	Quantity in system when irrigation began kg	Percent removed	Quantity irrigated	
				kg	percent
BOD_5	2,150	164	92	110	5
COD	7,350	297	96	198	13
Total solids	7,530	1,850	75	1,230	16
Volatile solids	5,050	308	94	204	4
Total phosphate	121	118	0	79	65

Note: [a] Based upon published swine waste characteristics.[9]

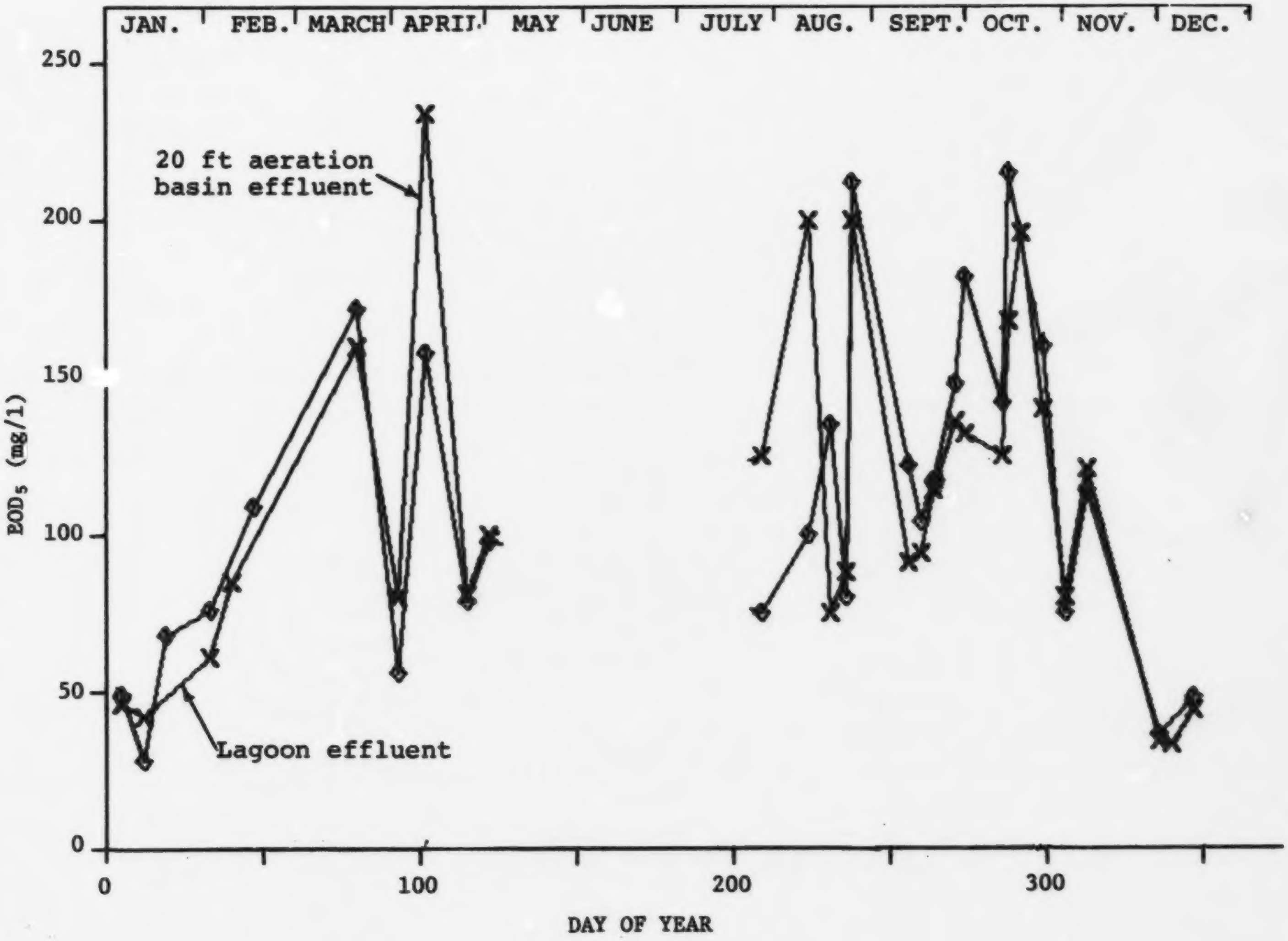


Figure 19. Lagoon effluent and 6-m aeration basin effluent BOD_5 concentration vs. time for the period of July 1971 to May 1972.

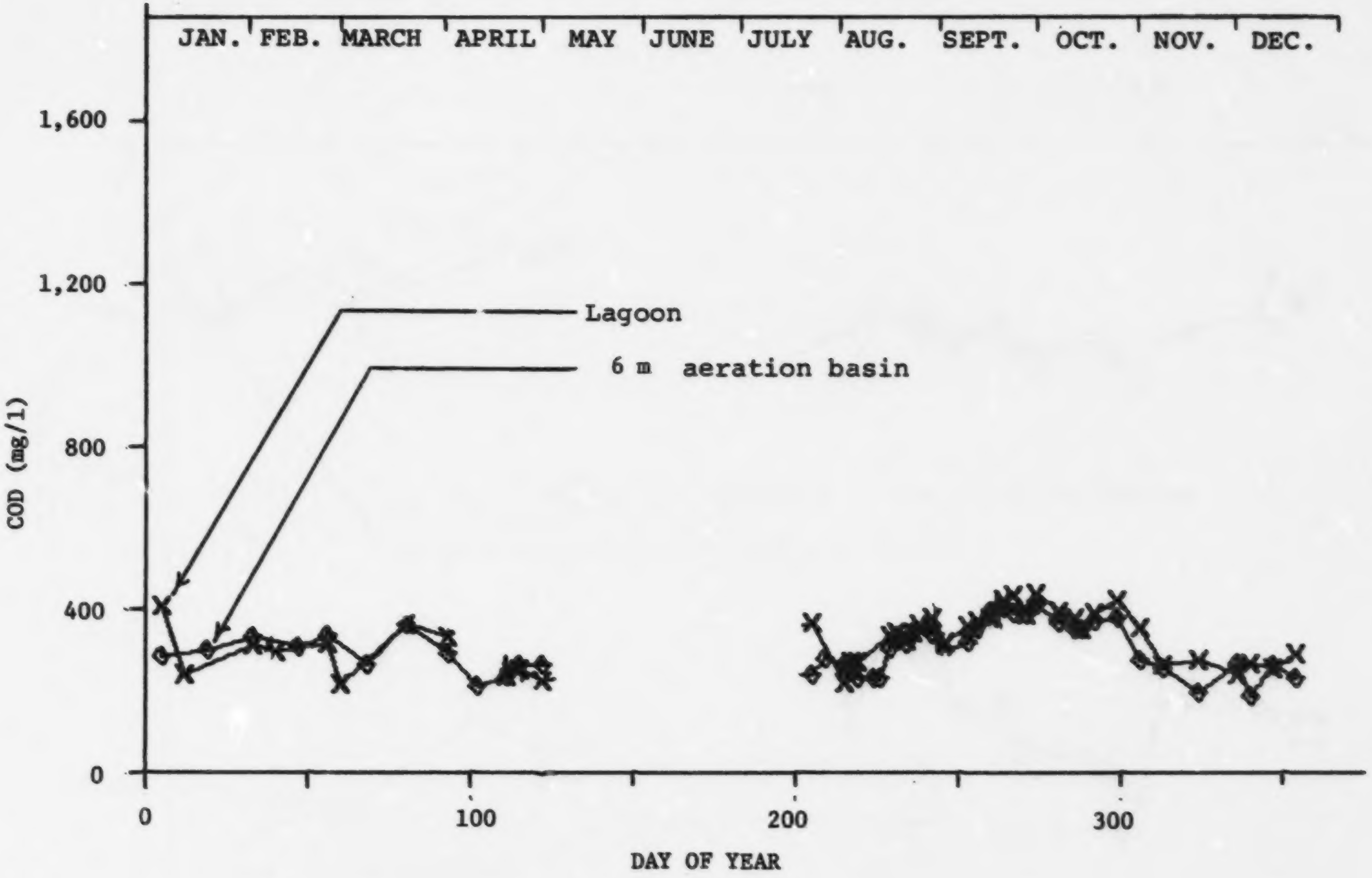


Figure 20. Lagoon effluent and 6-m aeration basin effluent COD concentrations vs. time for the period July 1971 to May 1972.

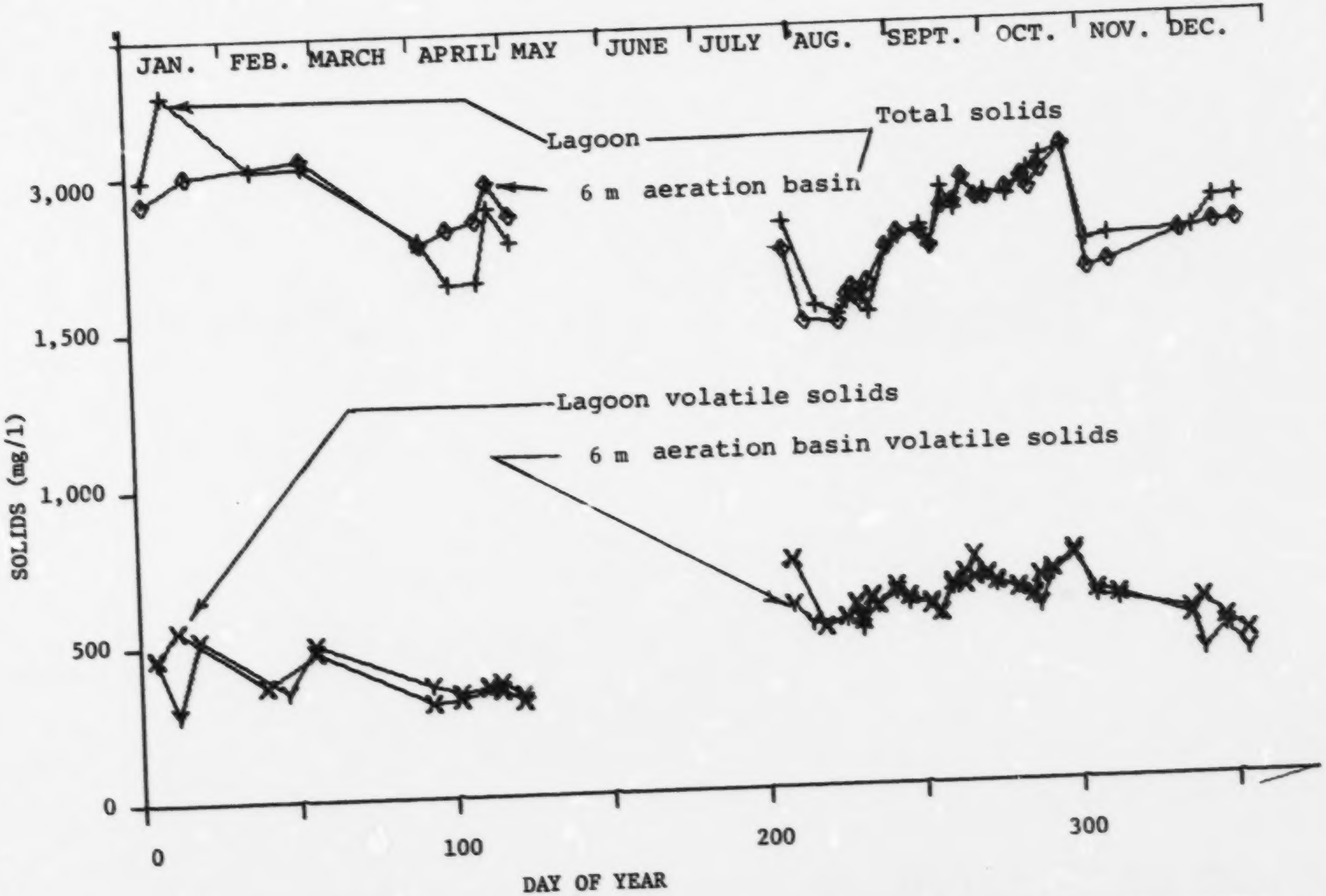


Figure 21. Lagoon effluent and 6-m aeration basin effluent total and volatile solids concentrations vs. time for the period July 1971 to May 1972.

The total phosphate concentrations in the lagoon and aeration basin were nearly equal and remained constant in the range of 10-25 mg/l from start-up until mid-September. Then the concentration increased to the range of 30-45 mg/l and remained there through the remainder of the test period. (Figure 22 and 23). These concentrations are somewhat lower than one would expect.

While the sows occupied the building from August 26 to October 26, 1971, the chloride concentration increased steadily (Figure 24), then remained relatively constant throughout the winter. The fluctuation in the chloride concentration was probably caused by sampling errors while there was an ice cover on the lagoon and aeration basin. On March 16, lagoon effluent was pumped to the RBC lagoon. Snow and ice melt and rain water then diluted the lagoon and aeration basin effluent thus lowering the chloride concentration. Since no animals occupied the farrowing buildings after April 11, the chloride concentration remained constant.

From July 22 until November 2, 1971, the pH in the lagoon (Figure 25) was relatively high, fluctuating from 8.0 to 8.6. The aeration basin pH (Figure 25) fluctuated between 8.4 and 8.8 during the same period. This slightly higher range for the aeration basin was probably caused by liberation of CO_2 as aeration occurred. After March 31, when the aerator was reinstalled, the pH increased in both the lagoon and aeration basin because CO_2 was again liberated.

The ammonia concentration remained low and fluctuated from near zero to 50 mg/l from start-up until the last week in February. From late February until mid-April sows occupied the farrowing buildings. The ammonia concentration was measured from the lagoon to the aeration effluent (Figure 26).

The nitrate concentration in the lagoon was 7.7 mg/l during mid-August (Figure 27). During this time the COD was low and aerobic conditions prevailed in the lagoon (Figure 20). This allowed the nitrifying organisms to convert ammonia to nitrate. The nitrate concentration in the aeration basin was at this same level. During late August, sows occupied the farrowing buildings and placed a higher organic load on the lagoon. The dissolved oxygen concentration remained below 1.0 mg/l after this time. Since nitrifiers are not able to live under anaerobic conditions, the nitrate concentration decreased in the lagoon.

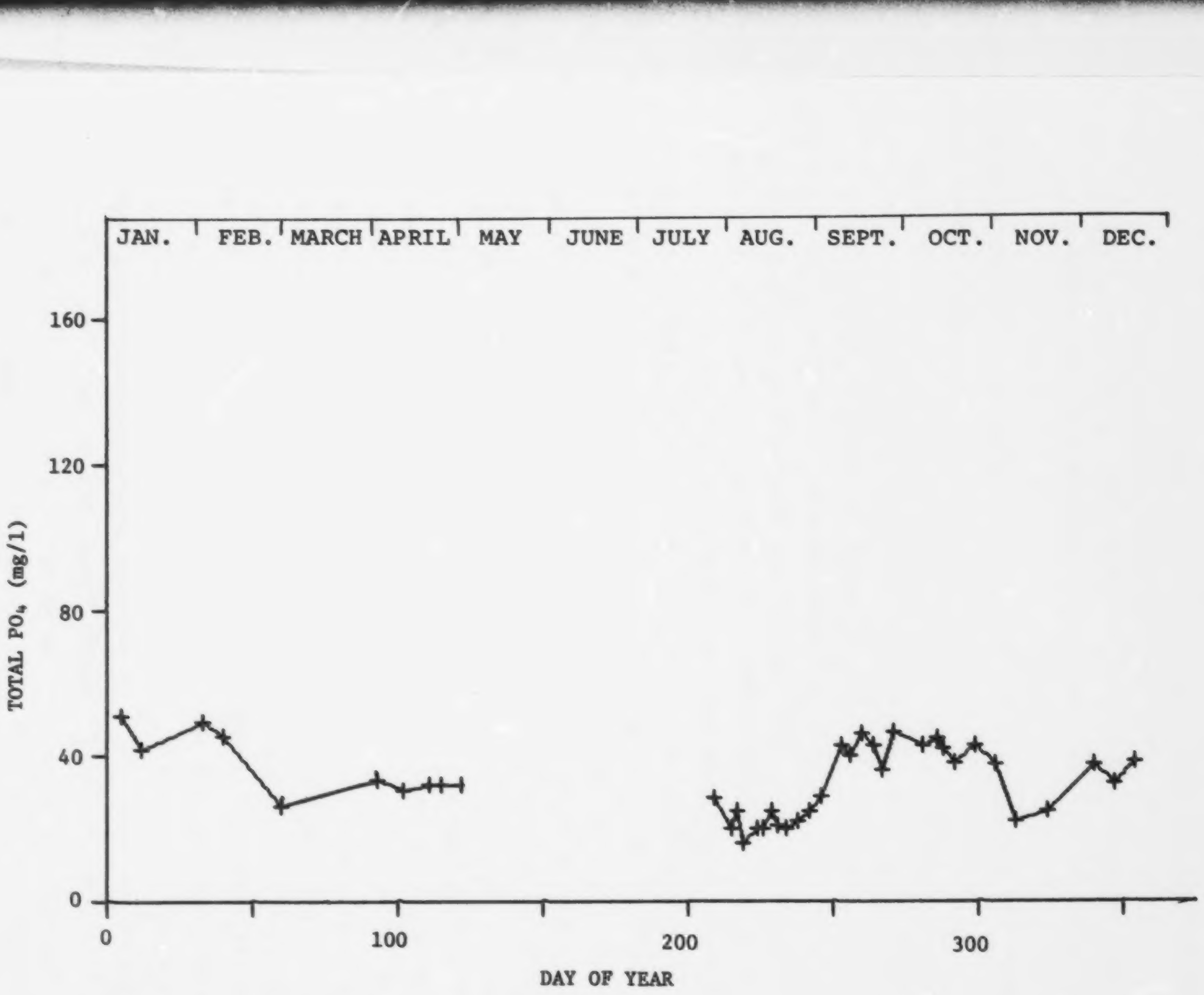


Figure 22. Lagoon effluent total phosphate concentrations vs. time for the period July 1971 to June 1972.

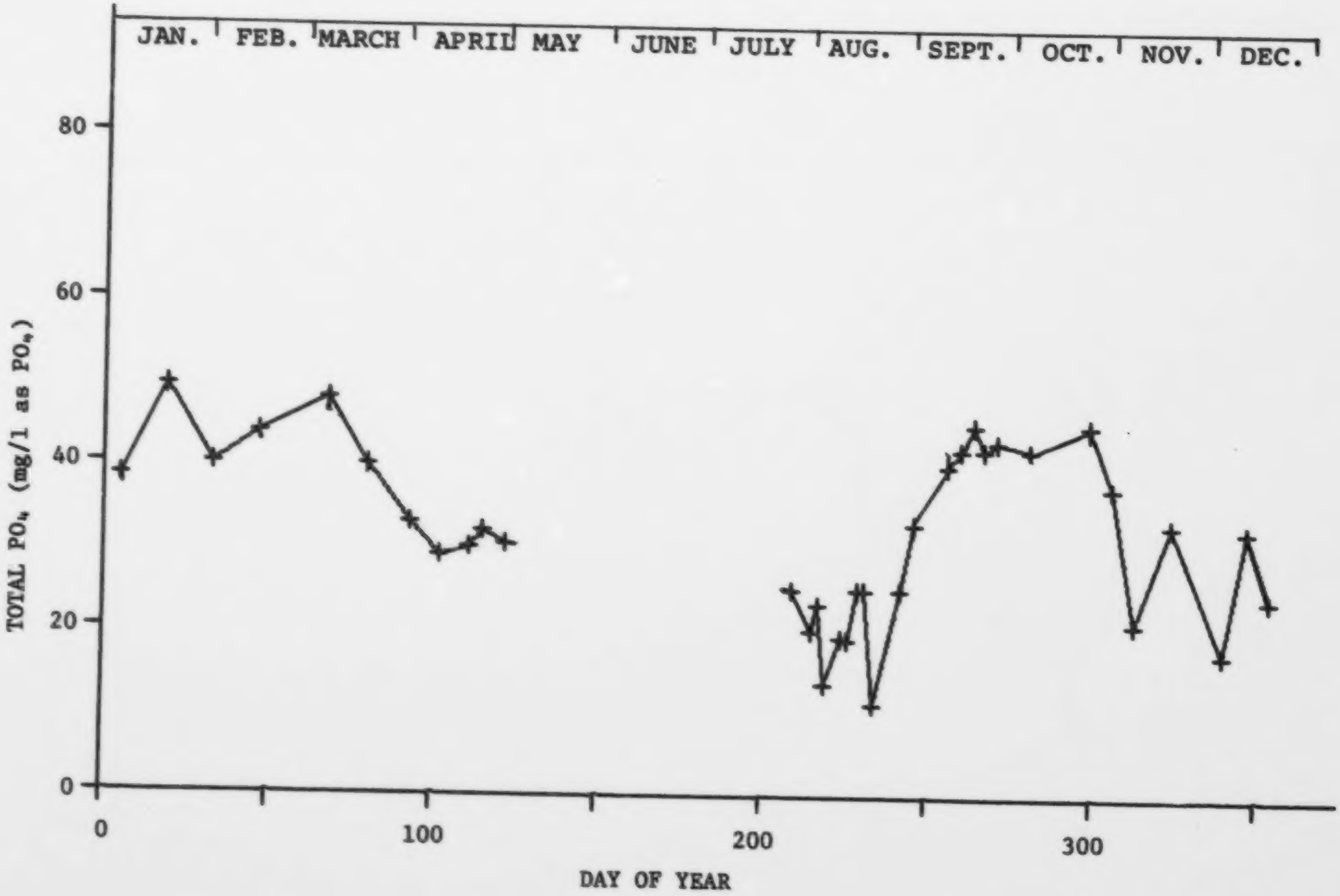


Figure 23. Total phosphate concentration vs. time for the 6-m aeration basin effluent for the period July 1971 to May 1972.

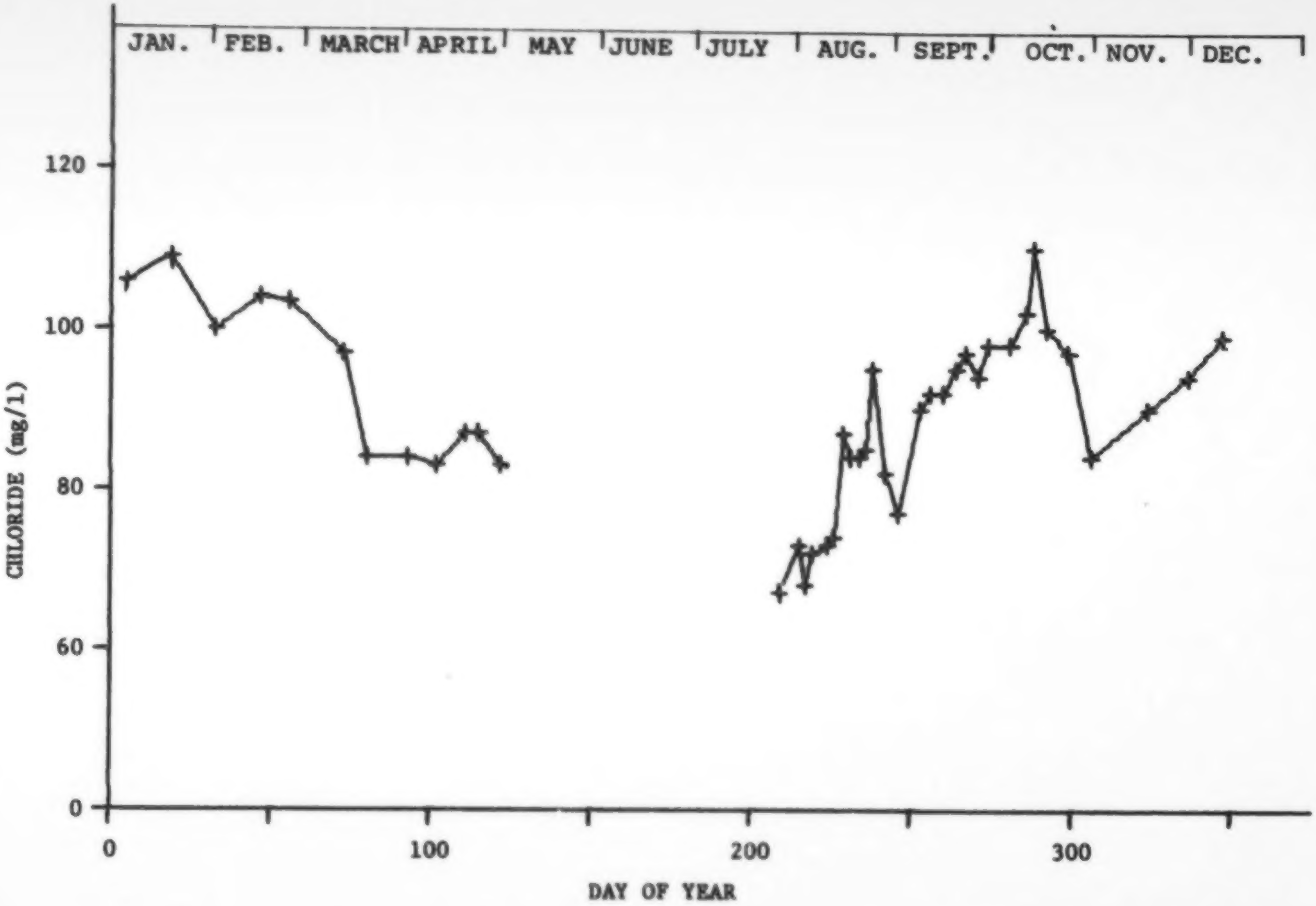


Figure 24. Chloride concentration vs. time for the lagoon-aeration basin system effluent for the period July 1971 to May 1972.

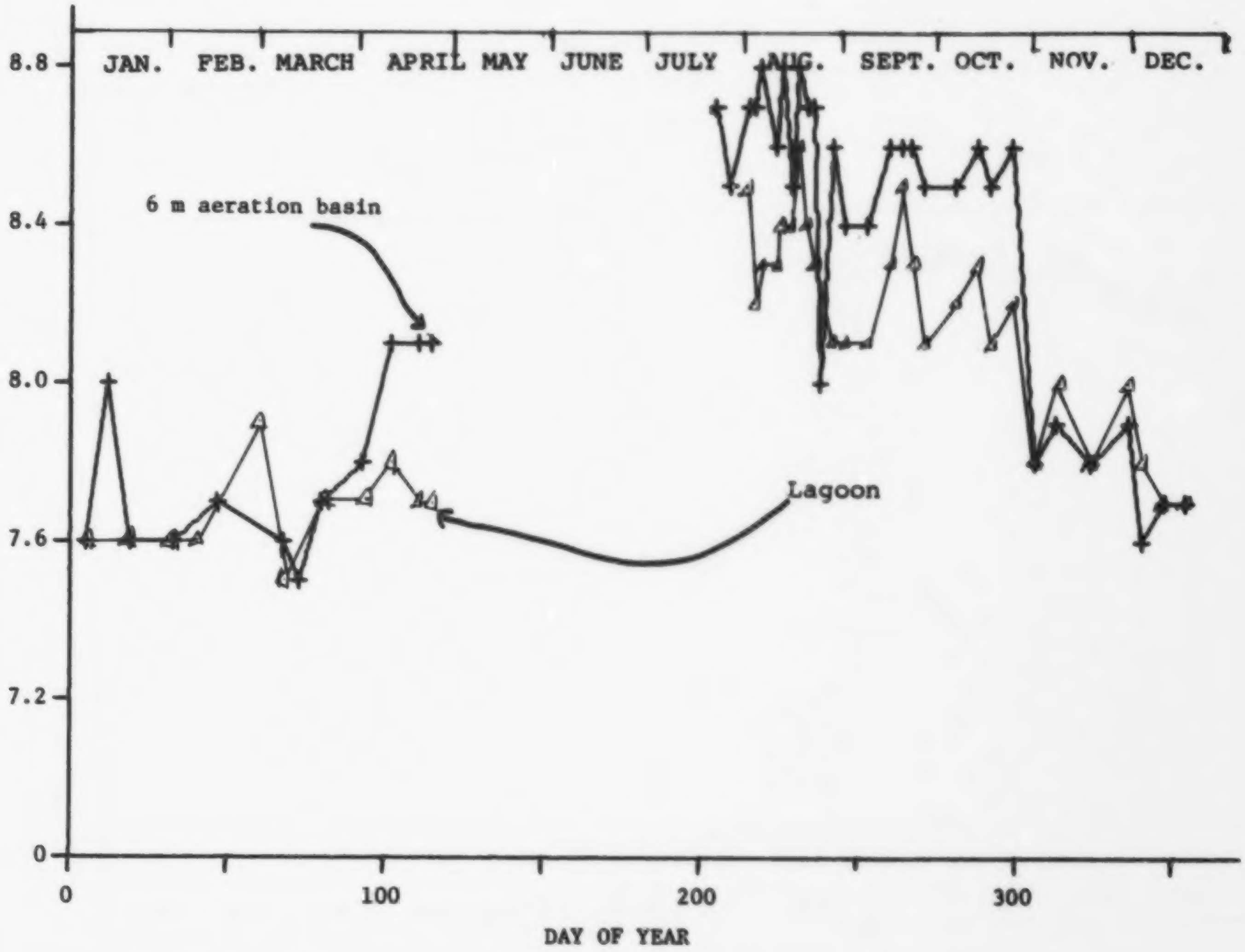


Figure 25. Lagoon effluent and 6-m aeration basin effluent pH vs. time for the period July 1971 to May 1972.

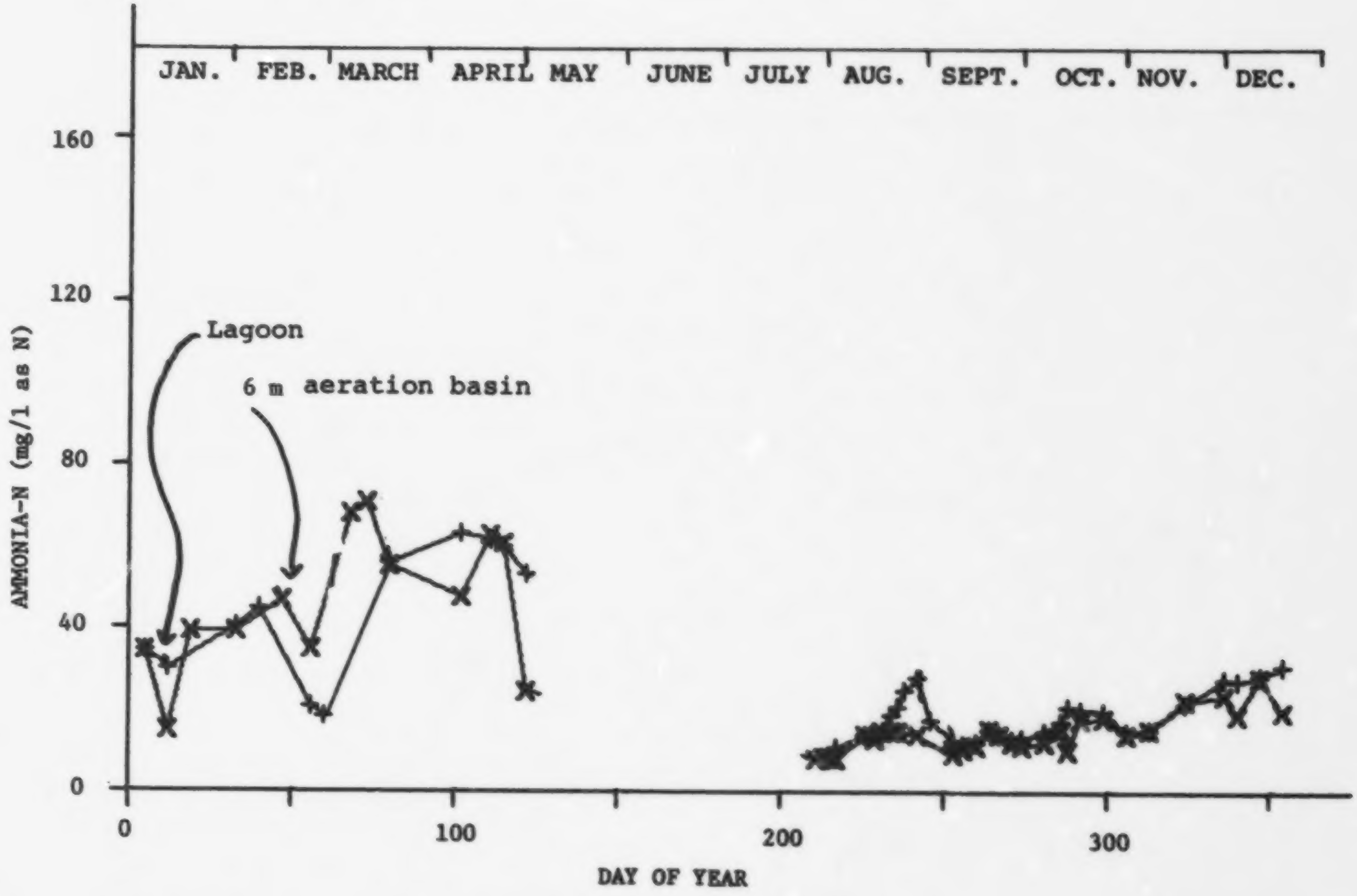


Figure 26. Lagoon effluent and 6-m aeration basin ammonia concentration vs. time for the period July 1971 to May 1972.

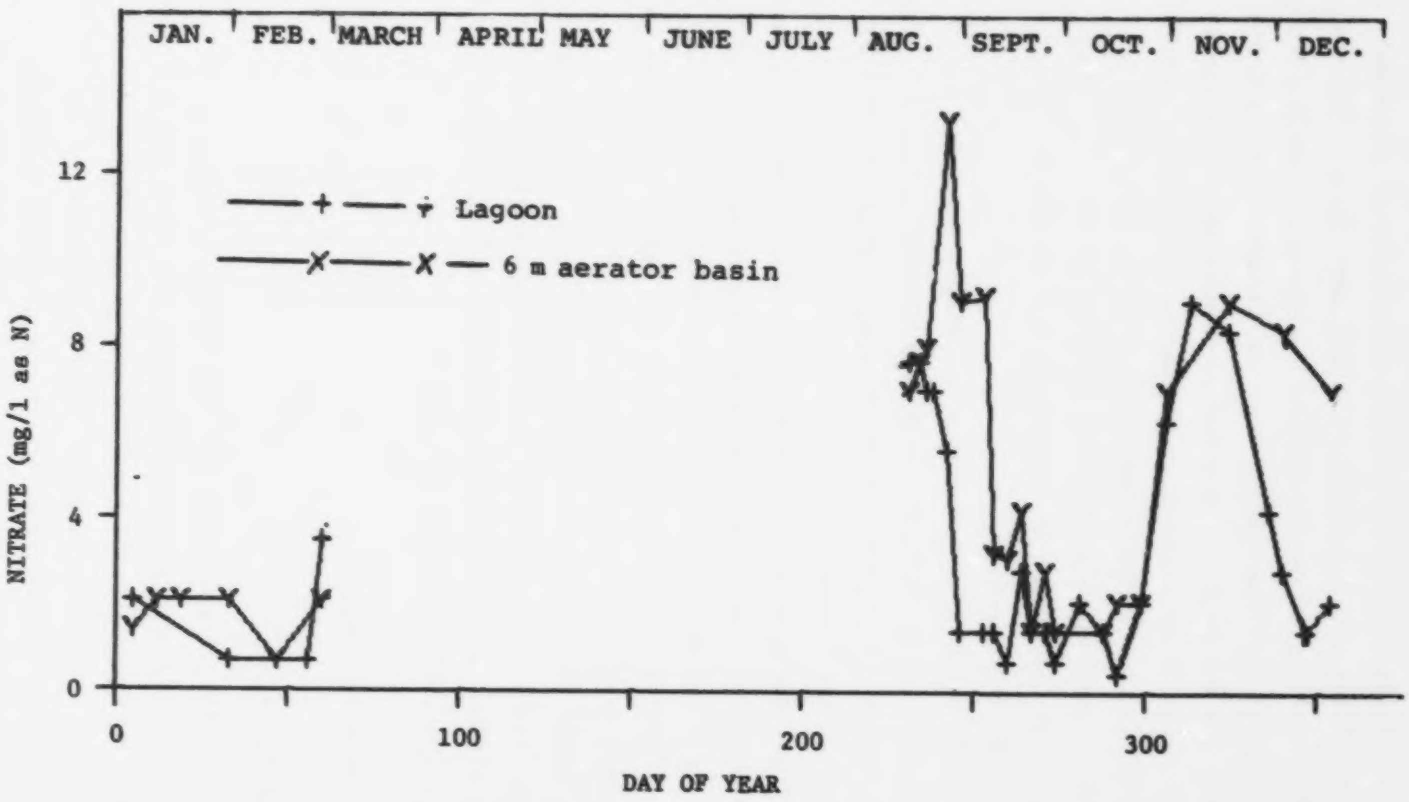


Figure 27. Lagoon effluent and 6-m aeration basin effluent nitrate concentration vs. time for the period July 1971 to March 1972.

The solids retention time in the aeration basin was not long enough to retain a population of nitrifiers and the nitrate concentration decreased in the aeration basin. After the farrowing buildings were vacant, the manure that had accumulated in the lagoon decomposed and the dissolved oxygen (D.O.) concentration in the lagoon increased to 5.4 mg/l on November 9 (Figure 28). After aerator removal, the aeration basin became an extension of the lagoon and the D.O. concentration in the basin was the same as that in the lagoon. A nitrifier population was able to establish itself in the lagoon and the nitrate concentration in the lagoon reached 9.1 mg/l on November 9. When the temperature dropped in late November, the nitrifiers became inactive and the nitrate concentration decreased.

What has just been described is a start-up phenomenon since one would expect a heavier organic loading situation in an established operation. The nitrifying organisms cannot compete for dissolved oxygen as effectively as organisms that metabolize carbonaceous material.

The organic nitrogen concentration (Figure 29) showed a gradual increase from late August until mid to late October while animals occupied the buildings. A slight decline in early October reflects the lower animal population in the system during this period. After late October, the organic nitrogen concentration remained relatively constant within the range 7-15 mg/l.

When animals occupied the buildings again, after late February, the organic nitrogen began to increase. After April 11, the system was unoccupied and the organic nitrogen concentration decreased as the waste material was decomposed and as rain water diluted the liquid.

ROTATING BIOLOGICAL CONTACTOR SYSTEM

Historical Account of Operation

The start up of the RBC system began July 22, 1971, and lasted 1-1/2 months. The biological lawn began as a light brown slime growth on all the disks. Within a week, the brown growth began to change to a chalky white growth at the outlet end of the disk section. During this time, a very heavy gray and white, marbled slime developed on the clarifier scrapers. The chalky-white growth on the disks gradually developed toward the inlet end of the disk section. As this occurred, the heavy slime disappeared

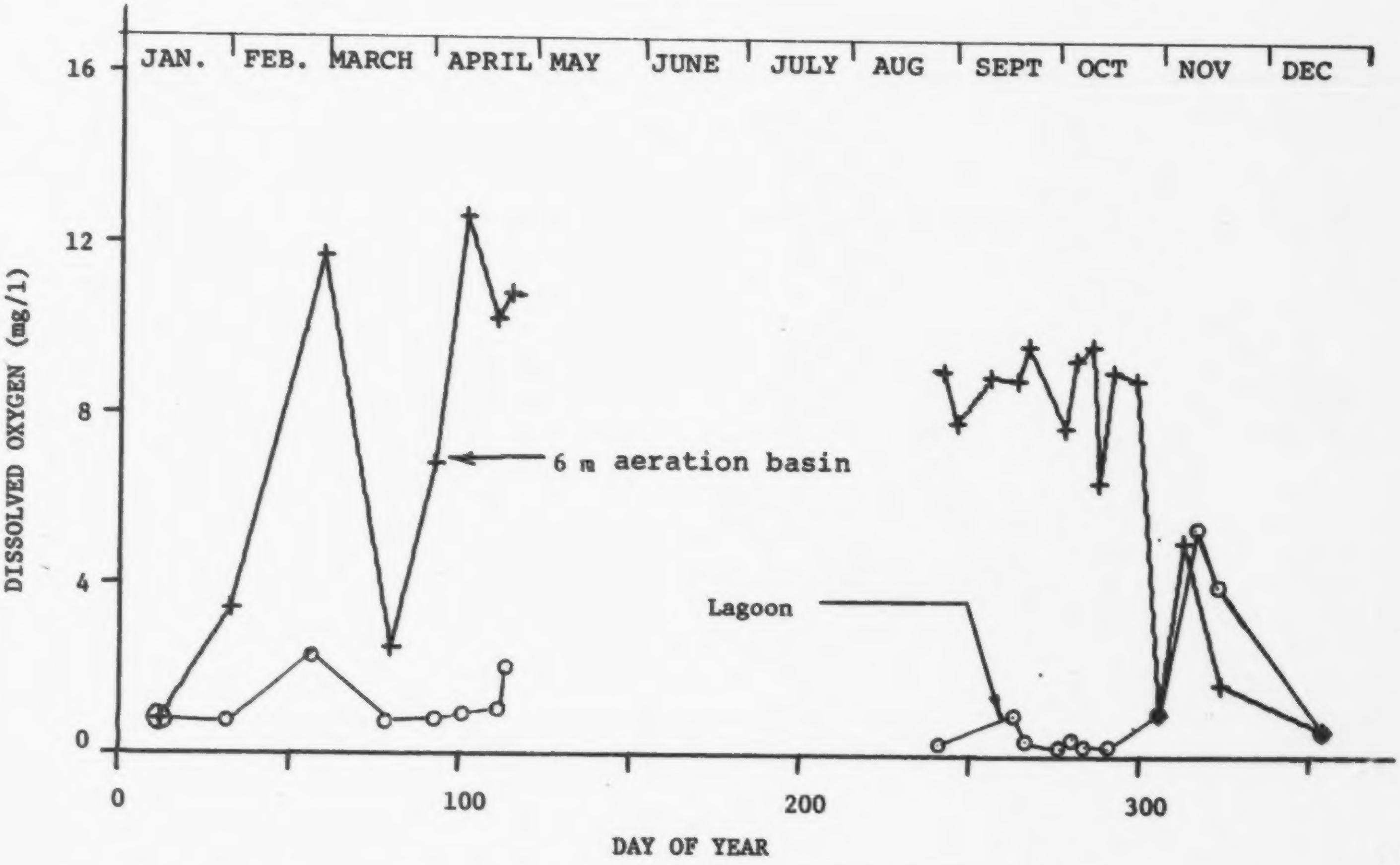


Figure 28. Lagoon effluent and 6-m aeration basin dissolved oxygen concentration vs. time for the period August 1971 to May 1972.

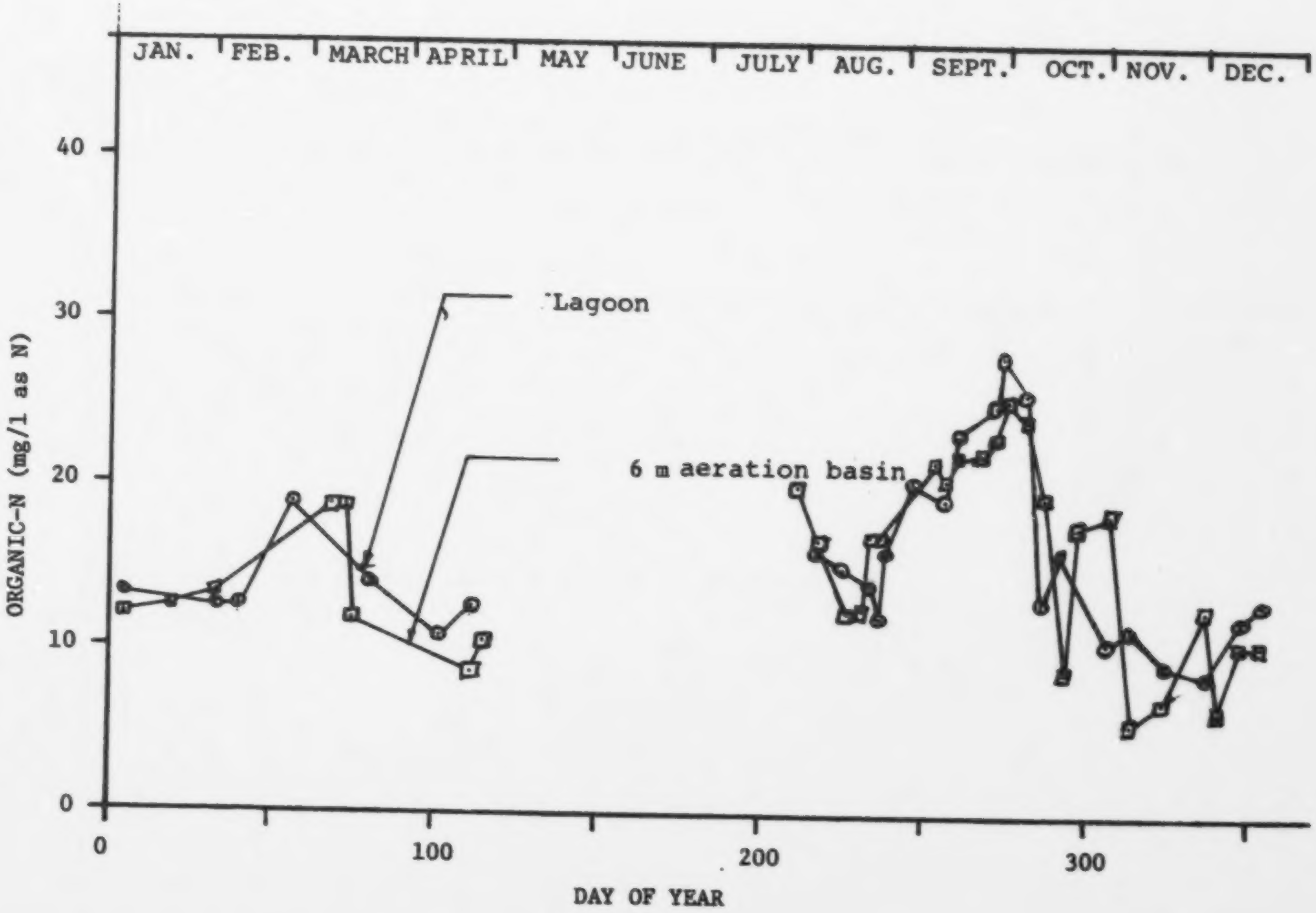


Figure 29. Lagoon effluent and 6-m aeration basin effluent organic nitrogen concentration vs. time for the period July 1971 to April 1972.

from the clarifier scrapers. One month after RBC operation, a 0.32-cm thick, grayish brown, filamentous slime growth began to develop at the outlet end of the disk chamber. Within two weeks, this growth had established itself on all the disks.

Lagoon effluent splashed into the sump from the overflow pipe and aerated the lagoon effluent (Figure 30). During the first four (4) weeks of operation, this aeration released large quantities of hydrogen sulfide (detected with moist lead acetate paper) that caused a distinctly objectionable odor. This odor dissipated after four weeks of operation.

Only a few mechanical problems were encountered from start-up through December. The drive and driven pulleys on the clarifier solids scraper were causing the drive belt to break. After proper adjustments were made, no further problems occurred. The sump pump which delivered lagoon effluent to the RBC was off periodically during November because of a thermal overload. The motor current was found to be above the recommended level. Further examination of the pump revealed that a deposit of calcium carbonate had formed on the impeller causing a drag force.

By the first week in December the odor of an outdoor privy had developed inside the RBC building and outside the building, especially near the exhaust fan. This odor prevailed throughout the remainder of the operating period. No odors were detected from the anaerobic lagoon during 1971.

The effluent returned to the hog buildings was not odorless but caused no odor problems in the buildings. The returned effluent was easily pumped and caused few clogging problems when the hydrant control valves were full-open.

The finishing animals were intrigued by the flushing water and made efficient use of the flushing gutters. They defecated and urinated in the gutter a large percentage of the time. In the buildings with the smaller pens, an area 0.3 to 0.5 m wide next to the gutter remained damp and contained an occasional dropping. The dampness was primarily from the pigs' wet feet as they walked from the gutter. The damp and dirty area in the larger pens was more extensive. This damp area decreased as the pigs grew and occupied more of the area for sleeping. The animals in all the buildings remained clean and dry.

The treated effluent discharged into the gutters effectively cleaned the manure from the gutters initially, except for a 3 cm deep by 15 to 20 cm wide wedge of manure that remained along the outside edge of the gutter.

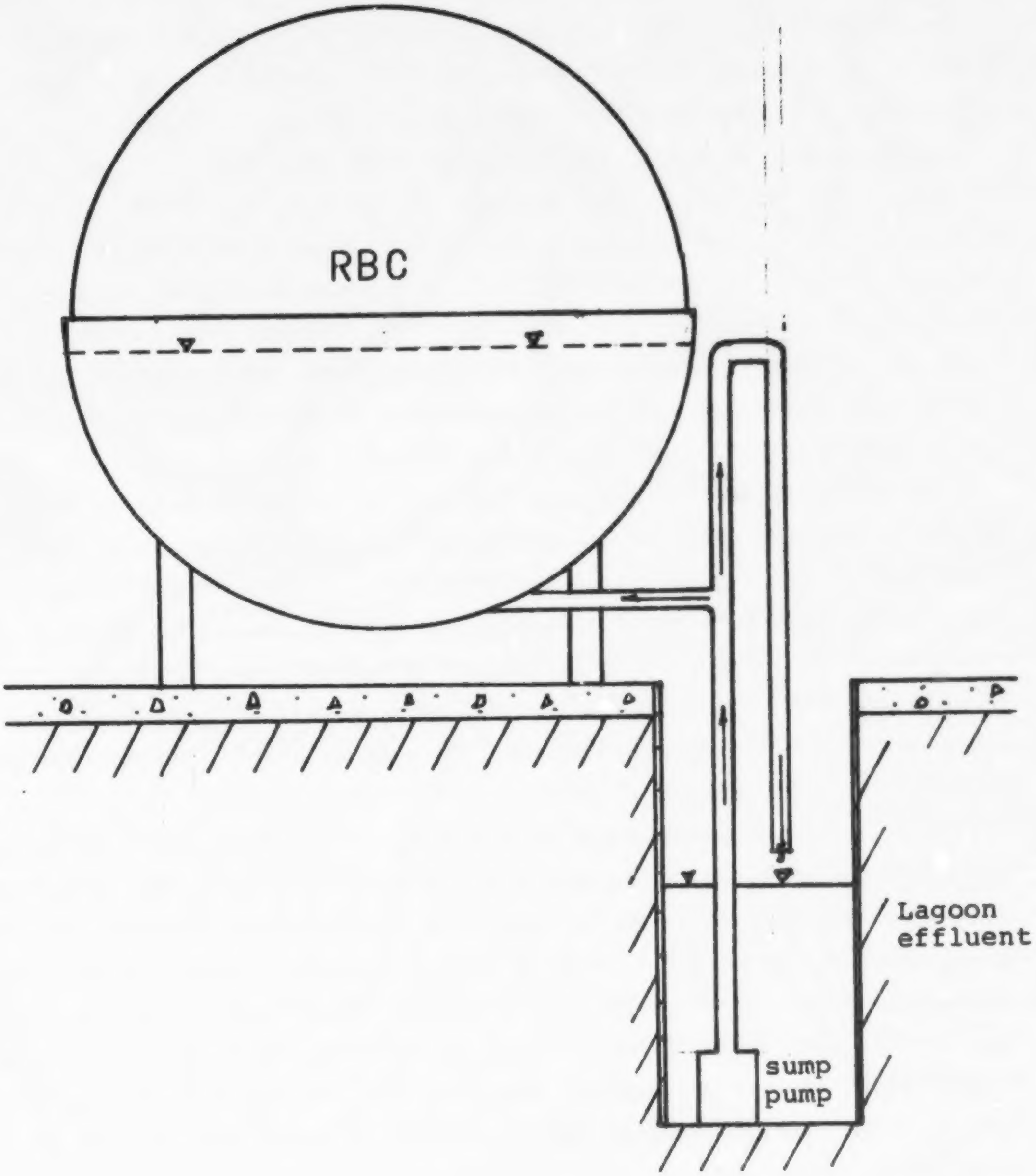

RBC
Lagoon
effluent
sump
pump

Figure 30. RBC overflow for wet well water level control.

In mid-November manure began to accumulate in the lower end of the gutter. Apparently, insufficient energy was left in the running water by the time it reached the lower end of the gutter to transport all the manure from the gutter. The total weight of hogs in the buildings had increased to 65,000 lbs. by this time. Flushing frequency was increased to remove the manure accumulation but was not successful. The manure was manually loosened daily in the gutter and extra water flushed down the gutter to remove the manure from the building. This occupied one man for two hours to remove the manure for 580 hogs. As the total weight of animals in the buildings decreased, manure accumulation became less of a problem.

Laursen[24] found that the sediment-carrying capacity T_F (weight/unit volume) of flowing water is approximately proportional to the fifth power of the flow velocity (V). That is

$$T_F \alpha V^5$$

from the Meyer and Weschmier's assumption that

$$V \alpha S^{1/3} Q^{1/3}$$

one can deduce that

$$T_F = S_F S^{5/3} Q^{5/3}$$

where S = channel slope (L/L)

Q = discharge (L^3/T)

S_F = a soil constant that accounts for the effect of particle size and density on the solids transportability ($L^{9/5}/T^{3/5}$).

One should note that manure has a considerably lower specific gravity than soil, thus bouyancy forces may also be important. From this, it appears that the ability of the water running down the gutter to remove manure should be sensitive to channel slope and the rate, Q, at which water is discharged into the gutter. Increasing the discharge rate of treated effluent into the gutter needs to be explored to see if this can improve manure removal. The flushing gutter (Unit K) reported by Smith, et al.[12] had a slope of 0.3 m in 37 m or .83 percent and operated satisfactorily with a 415-1 flush every hour. One difference in their building was that the weight of animals per foot of gutter was smaller than the Bilsland site, the reason being that at Bilsland the buildings were filled with 15-25 kg pigs at the beginning of a growing cycle. These animals then remained in the buildings until they reached market weight. At Unit K, market weight animals are continually being removed and replaced with animals weighing 10-20 kg.

During mid-December calcium carbonate and perhaps magnesium ammonium phosphate had deposited on the sump pump enough that the impeller would no longer turn. This deposit was chipped from the impeller housing and the pump returned to operation. The pump remained in operation for three months before it had to be cleaned of the crystals again. Inability to service the pump in place made the problem more severe. About seven man-hours were needed to service the pump.

During mid-January calcium carbonate crystals 0.25 cm long by 0.05-0.10 cm in diameter appeared as yellow-brown crystals in the disk section of the RBC. These crystals entered the clarifier and settled readily. However, the sludge scraper did not remove the calcium carbonate crystals effectively. The scraper picked up the crystals as it passed through the bottom of the clarifier. As the scraper lifted from the water, the water between crystals escaped rapidly and the crystals adhered to the scraper as a cohesive mat. As the scraper continued its circle, the scraper tipped upside down and the calcium carbonate crystals fell from the scraper back into the clarifier. The calcium carbonate crystals accumulated in the disk section to such a depth that the biological lawn was scraped from the periphery of the disks as they passed through the accumulated crystals on the bottom of the disk section. These crystals had to be removed from the RBC every 10-15 days from mid-January until mid-April. Removal required opening the drain valves, completely draining water from the RBC, and then hosing the crystals from the RBC through the drain valves to the floor. The crystals were then scooped from the floor and carried from the building. This required about eight man-hours of labor.

The following analysis was conducted to shed some light on the calcium carbonate problem.

Temperature = 5° C., Dissolved Solids 2200 mg/l
Calcium Hardness = 2300 mg/l as $CaCO_3$
Total Alkalinity = 1500 mg/l as $CaCO_3$
pH = 8.0

Chemical equilibriums of $CaCO_3$ showed that calcium carbonate should indeed precipitate. Apparently the mixing of the effluent in the disk section adds enough energy and raises the temperature sufficiently to cause crystallization to occur.

For the RBC to be an effective treatment device for treating lagoon effluent, the problem of calcium carbonate precipitation must be overcome. One alternative may be to precipitate the calcium carbonate before the liquid enters the RBC. The precipitated crystals would then have to be removed at that stage. Another option would be to find a convenient means to remove the precipitated crystals from the RBC as they form. This could possibly be done by installing four corrosion-resistant metal rods equally spaced on the periphery of the disks. The scraper should be redesigned so that the sides of the scoops form an angle 30-60 degrees with the horizontal as they leave the water surface. This would cause the crystals to enter the sludge scraper and be removed rather than accumulate. Then the calcium carbonate would be returned to the lagoon and not removed from the system; however, it might allow more satisfactory operation of the RBC.

During mid-March crystals began accumulating in the hose that delivered treated effluent to the flush tanks and had to be removed periodically. By mid-April the return flow rate had significantly decreased. The return lines were acid cleaned with a one-percent solution of glacial acetic acid which had a pH of 4.5. This removed the crystals and the normal flow rate was regained.

During November through April, the drive chain and sprockets wore faster than normal. The sprockets and chains were enclosed in a housing containing oil for chain lubrication; however, water splashed into the housing and displaced the oil. The chain then frequently ran in lagoon effluent causing the chain to corrode and become inflexible causing accelerated wear. Misalignment of the sprockets also contributed to this chain-wear problem. New sprockets, drive chain, motor mounting, and wick-type chain oiler were installed. The drive mechanism has since operated satisfactorily.

Another constant chore was to tighten the packing on the return pumps every one or two weeks to prevent leakage. This packing was replaced once during the 11-month test period.

Water Quality

Table 9 shows the BOD_5, COD, and total and volatile solids, and total phosphate produced by the finishing hogs; the quantity of these parameters that were in the system just before irrigation began; and the quantities

Table 9. WASTE TREATMENT PERFORMANCE OF THE RBC SYSTEM DURING THE PERIOD JULY 1971 TO APRIL 1972.

Item	Quantity added by raw manure,[a] kg	Quantity in system when irrigation began, kg	Percent removed	Quantity irrigated, kg	Percent applied to the land
BOD	13,700	3,700	73	1,210	3
COD	46,700	7,850	83	2,670	6
Total solids	47,000	10,900	77	3,600	8
Volatile solids	30,500	4,480	86	1,480	5
Total phosphate	775	318	59	104	13

Note: [a] Based upon published swine waste characteristics.[9]

applied to the land through irrigation. The BOD_5, COD, and total and volatile solids reduction is similar to that found by Willrich[6], and Smith, Hazen, and Miner[12], for anaerobic lagoons. The total phosphate reduction is somewhat more than one would expect. However, some phosphate removal has been observed by others.[23] This has been attributed to precipitation of calcium and magnesium compounds. This hypothesis has been documented in laboratory studies by Ferguson.[25]

Of the total BOD_5, COD, and total and volatile solids only 8, 6, 8, and 5 percent respectively of that produced was actually applied to the land. Therefore, significant treatment of the carbonaceous fraction has occurred. As will be shown later, most of this removal occurred in the anaerobic lagoon.

Finishing animals had occupied the buildings for two months before the RBC began operation. Fresh water was used for gutter cleaning during that time. The anaerobic lagoon effluent BOD_5 (Figure 31) ranged from 250-86 mg/l while the COD (Figure 32) ranged from 820-377 mg/l from July 24, 1971,until the first week in November,1971. The COD loading ranged from 1,150-1,200 g COD per day-m^3. As the lagoon water temperature (equal to RBC influent temperature shown in Figure 33) decreased, anaerobic activity decreased and the BOD_5 and COD increased from early November until mid-March. During this time, the largest BOD_5 reduction measured was 50 percent which occurred through November and December. No BOD_5 or COD removal was measured from mid-January until late March and early April when a maximum of 27 percent BOD_5 removal was measured. This occurred after dilute water from the aeration basin lagoon was pumped into the RBC lagoon. The BOD_5 and COD concentration continued to increase until mid-April. After mid-April, anaerobic activity increased, the finishing hogs were removed from the buildings, and the BOD and COD concentration decreased. Virtually no BOD_5 or COD removal was measured in the RBC from mid-April until early June. The flow rate through the RBC was 2300 l per hr at this time. During the period mid-April through June, the COD loading rate ranged from 16,000 down to 12,500 g COD/day-m^3.

In an effort to better understand the RBC and its performance, long-term BOD analyses of the influent were run on February 28 and again on July 31, 1972. Those data are plotted in Figure 37 with both the untreated sample and the similar one treated with a nitrification inhibitor shown. Those

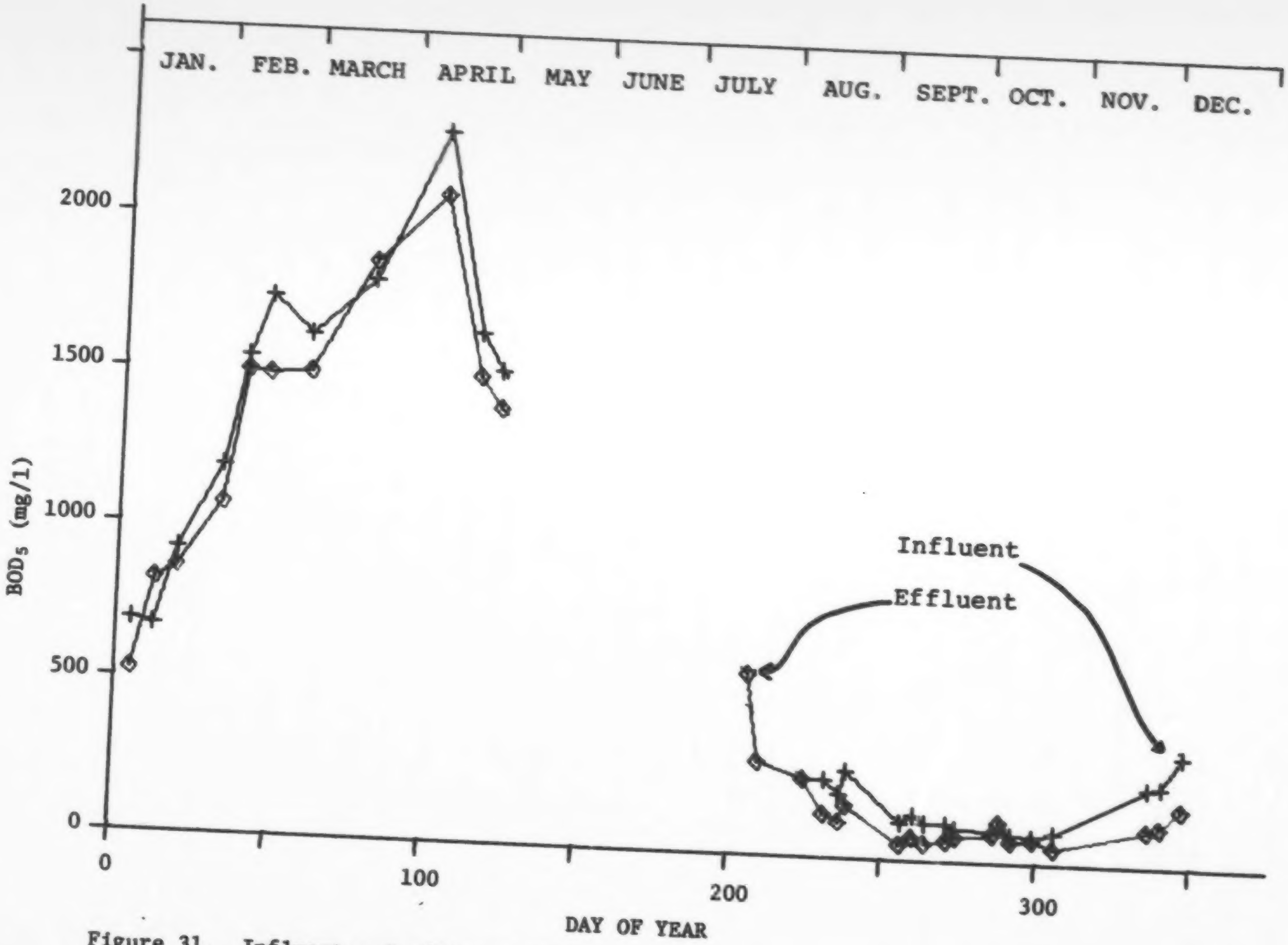


Figure 31. Influent and effluent BOD$_5$ concentration vs. time for the RBC during the period July 1971 to May 1972.

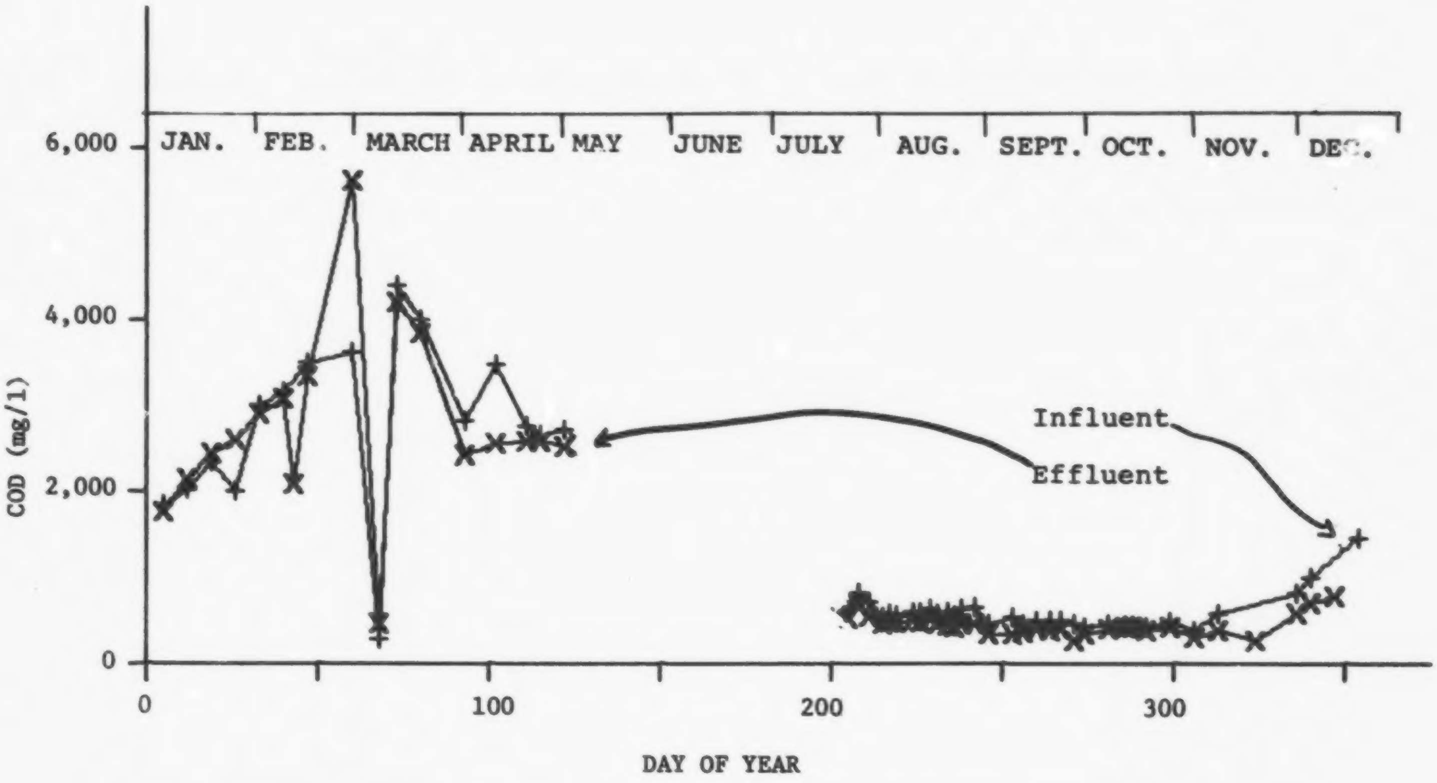


Figure 32. Influent and effluent COD concentrations vs. time for the RBC during the period July 1971 to May 1972.

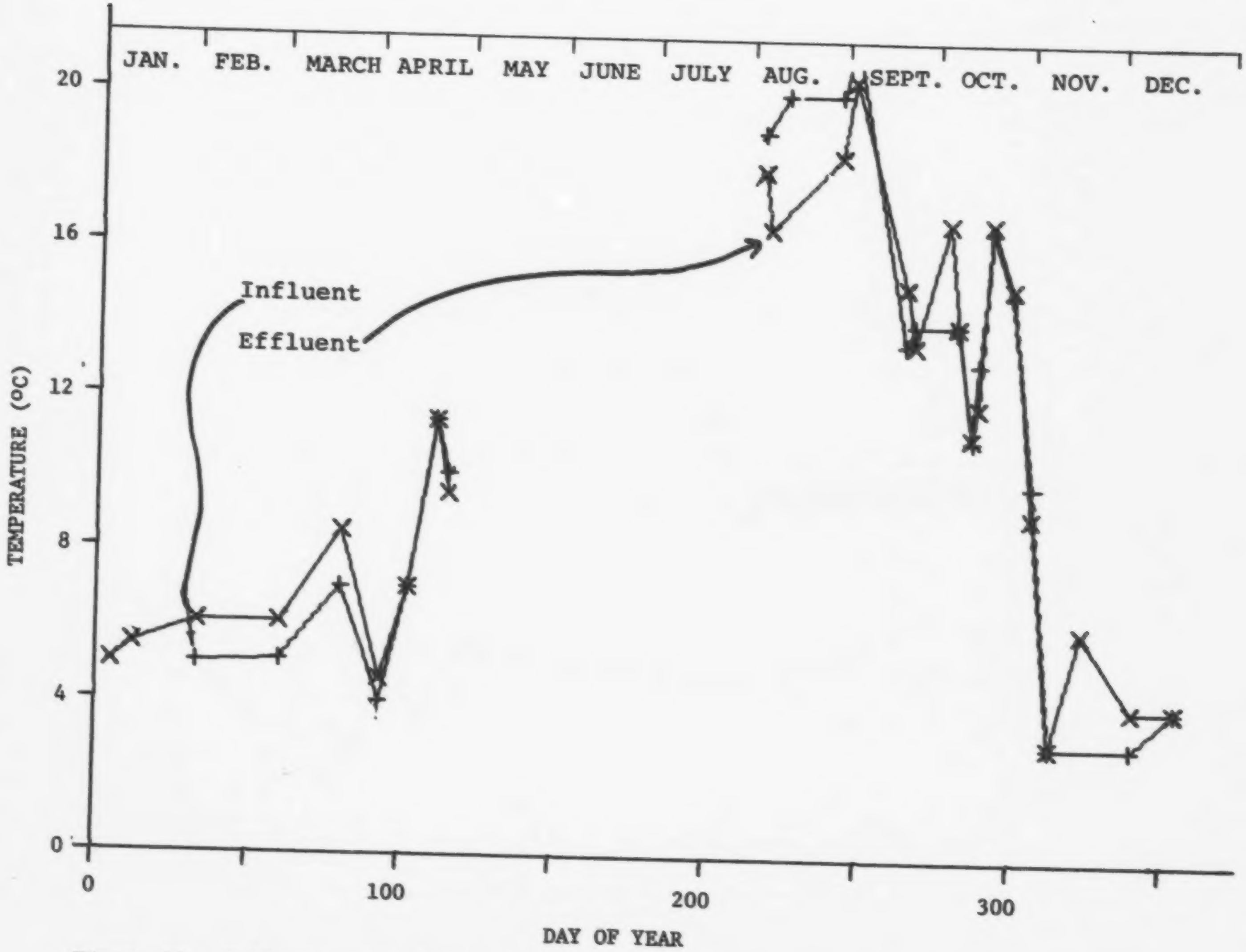


Figure 33. Influent and effluent temperature vs. time for the RBC during the period July 1971 to May 1972.

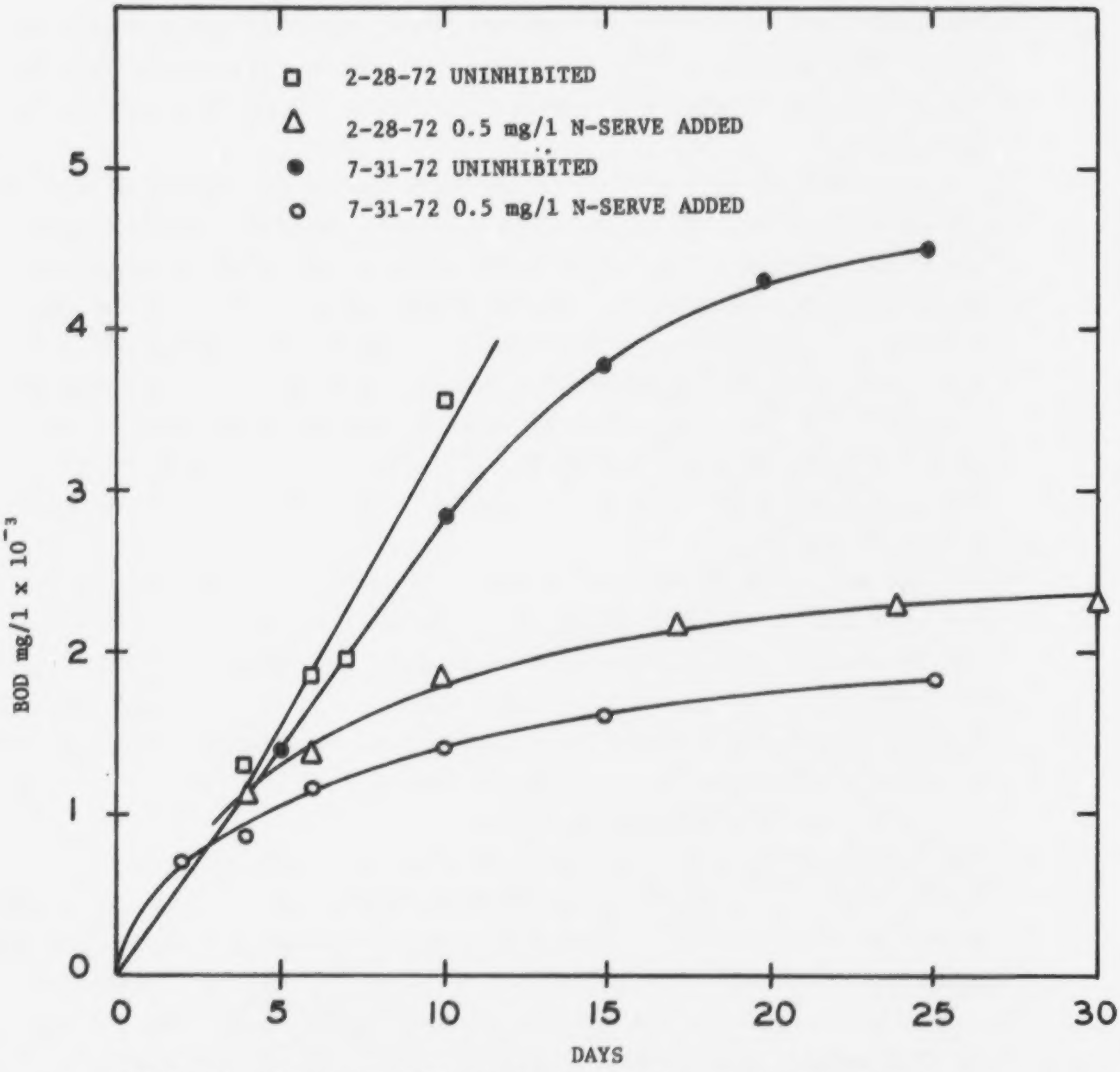


Figure 34. Long term BOD results obtained by analysis of RBC influent samples on February 28 and July 31, 1972.

curves reflect the relatively low rate constant and high nitrification demand that would be expected of anaerobic lagoon effluent.

Welch's data[26] would indicate that the RBC was overloaded during this time and one could not expect more than 30 percent COD reduction. From these data even if the disk speed were doubled, the COD reduction would not be above 35 percent. Again, from Welch's data,[26] one could estimate that the loading rate would need to be reduced by 1/2 to 2/3; and to maintain the 2,300 l per hr flow rate needed for gutter cleaning, the disk chamber volume would have to be doubled or tripled to decrease the loading rate sufficiently. This larger, more expensive equipment may not be economically justified.

The total and volatile solids concentrations in the lagoon effluent and RBC effluent (Figure 35) remained relativley constant from late July until early November,1971. After early November, temperatures decreased and both the total and volatile solids increased in the RBC influent and effluent until mid-March. Only slight reduction of total and volatile solids were measured through the RBC during this time. After dilution on March 16, 1972, the total and volatile solids concentration remained constant since the finishing buildings were vacant from early April until early June. Virtually no change in solids concentration occurred through the RBC (Figure 35).

The pH fluctuated between 7.8 and 8.2 throughout the last period. From late July until mid-September, 1971, the RBC influent pH was lower than that of the effluent. From mid-September until late December, this situation reversed. During January and February,1972, the effluent and influent pH were nearly equal. During the warmer weather from March to June anaerobic activity in the lagoon depressed the RBC influent pH. As the effluent was aerated in the RBC the pH increased.

The dissolved oxygen concentration (Figures 36 and 37) in the RBC influent and the effluent fluctuated between 0 and 4 mg/l. During September through November, 1971, the organic load was low enough that 1-3.8 mg/l was maintained in the RBC effluent. After November, the RBC was loaded more heavily and the D.O. in the effluent remained below 1 mg/l. The D.O. in the disk chamber varied from 1-2 mg/l.

During the early period of operation, July through October, the lagoon was operating aerobically and was able to support nitrifying organisms, and

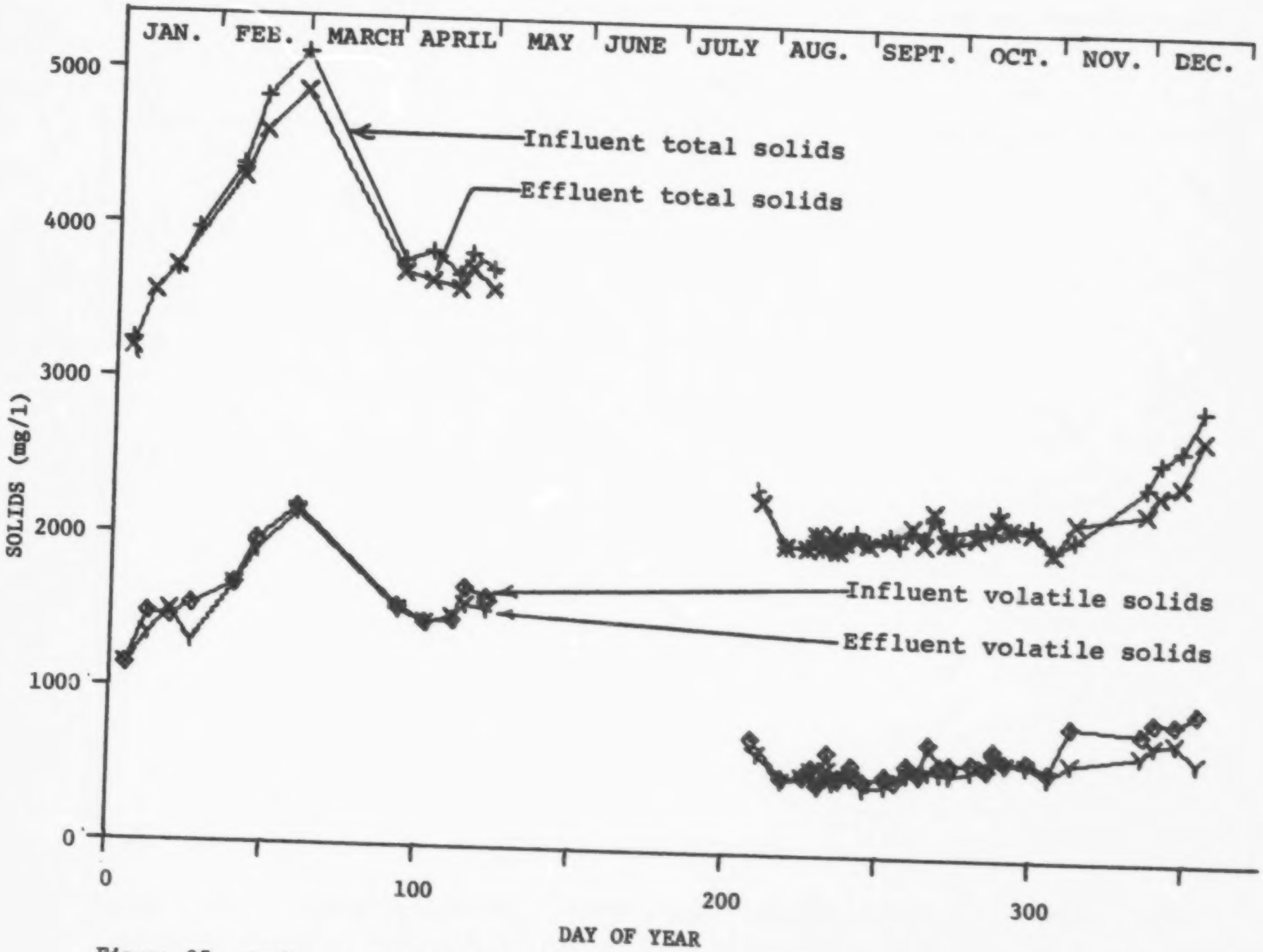


Figure 35. Influent and effluent total solids and volatile solids concentration vs. time for the RBC during the period July 1971 to May 1972.

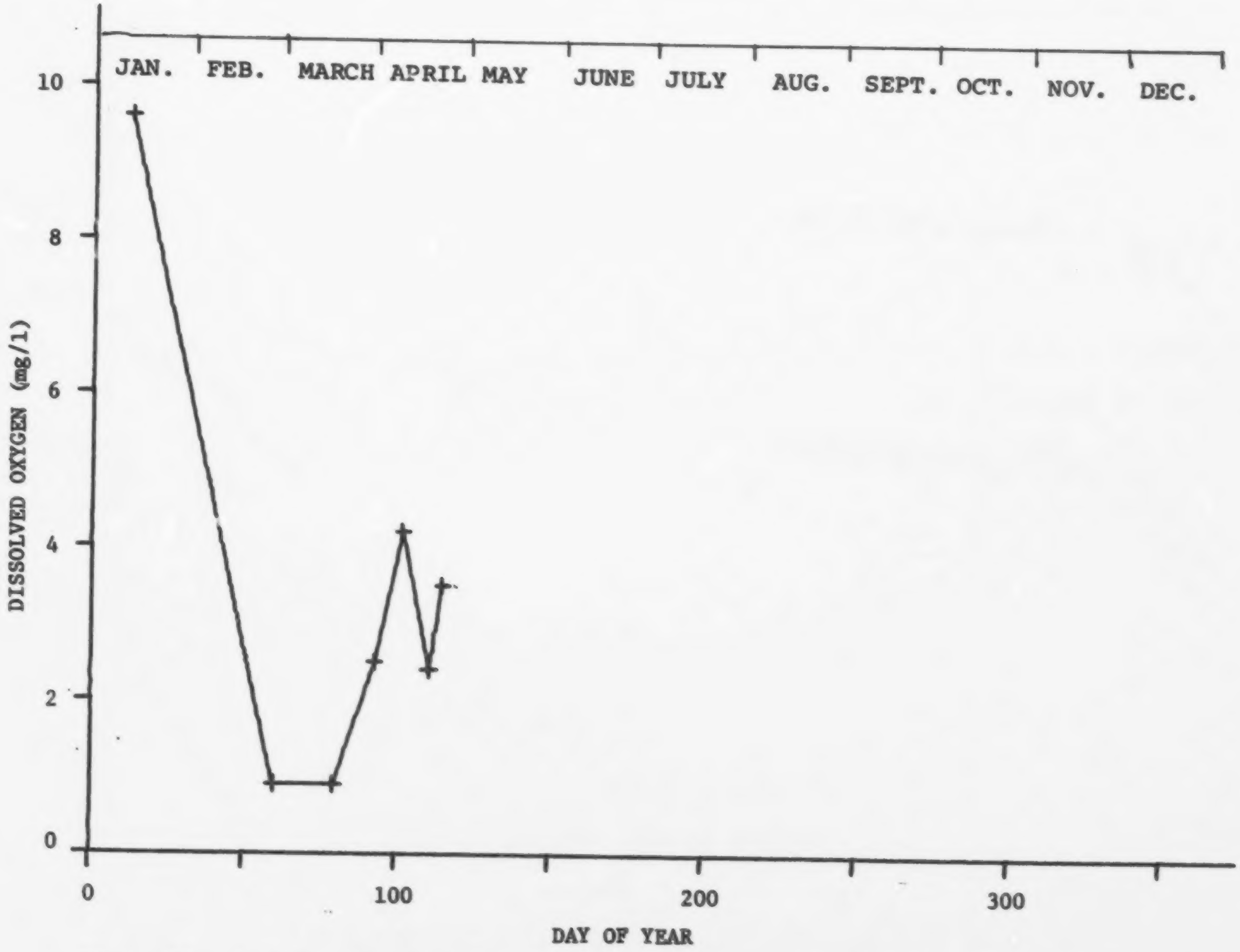


Figure 36. Influent dissolved oxygen concentration vs. time for the RBC during the period January to April 1972.

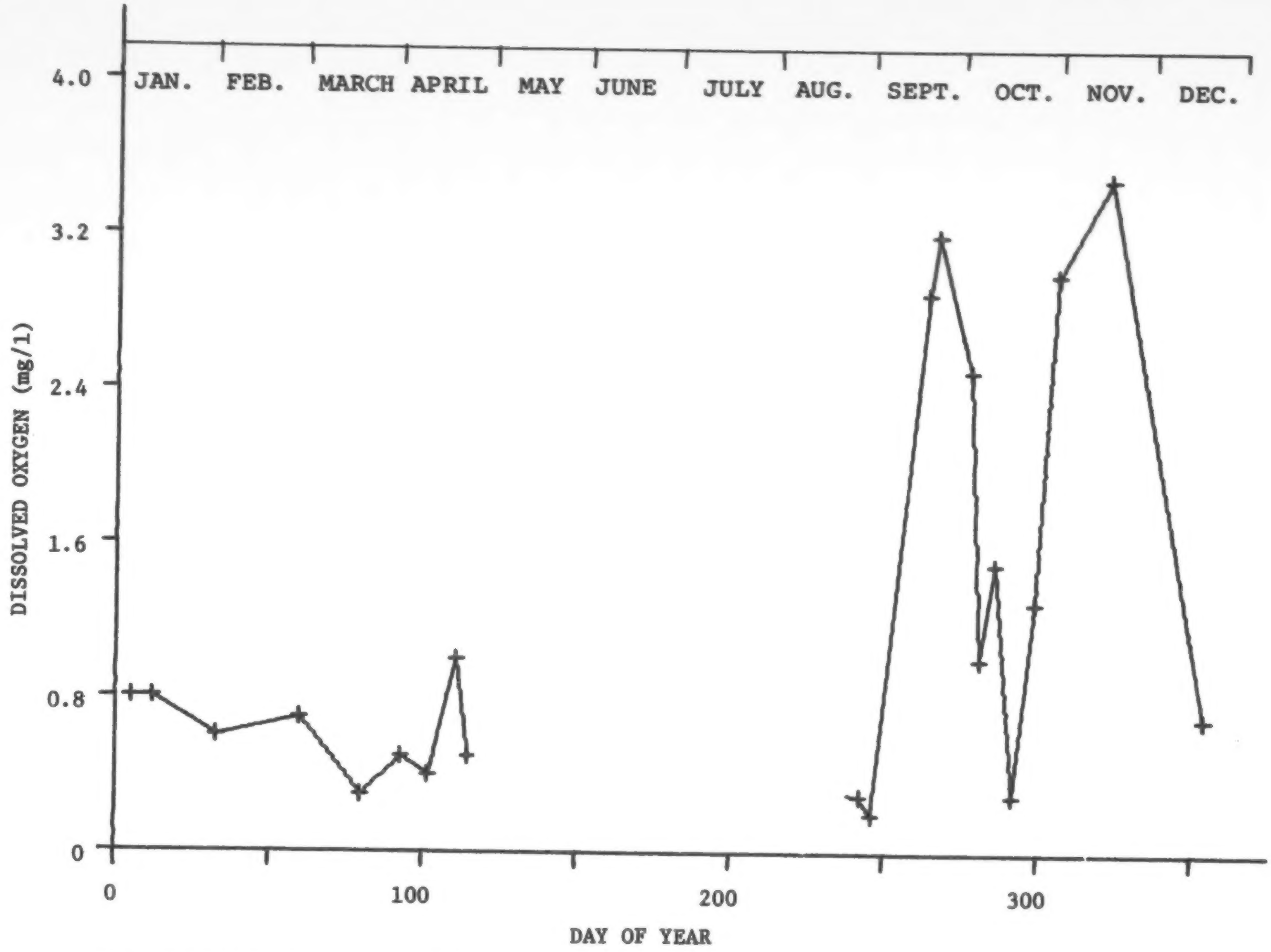


Figure 37. Effluent dissolved oxygen concentration vs. time for the RBC during the period August 1971 to May 1972.

the RBC influent contained up to 9.4 mg/l nitrate (Figure 38). As the temperature decreased, nitrification slowed in the lagoon. During November and early December, 1971, a nitrifier population became established on the RBC disks since the BOD_5 was low enough that nitrifiers could compete effectively for oxygen. The nitrate concentration in the RBC effluent reached a maximum of 47.6 mg/l. This is a start-up phenomenon and should not occur during normal operation with heavier organic loading. Nitrate concentrations remained near zero for the remainder of the test period.

The ammonia concentration (Figure 39) followed the same general pattern as did the total and volatile solids. Ammonia removal occurred only while nitrification occurred during November and early December, 1971. Organic nitrogen (Figure 40) ranged from 12.6 to 100 mg/l throughout the test and followed the same general trends as the solids concentration.

The effluent chloride concentration was nearly the same as that of the influent concentration (Figures 41 and 42). The chloride concentration remained fairly constant from July to November, 1971. It then began to increase until the lagoon liquid was diluted on March 1, 1972. After hogs were removed from the buildings, the chloride concentration remained constant until the end of the test. One would expect the chloride concentration in this system to reach an equilibrium as excess effluent is irrigated and some salts are removed. This equilibrium will probably not be such that it will be toxic to bacteria.[23]

The total phosphate concentration did not change appreciably as the lagoon effluent flowed through the RBC. (Figures 43 and 44). The total phosphate remained relatively constant from July through November, 1971. From early December until early March, the phosphate concentration increased as manure was accumulating in the system. During mid-March the lagoon was diluted by water from the lagoon-aeration basin system and the total phosphate concentration decreased. These concentrations were never in a range that would cause toxic effects to bacteria.

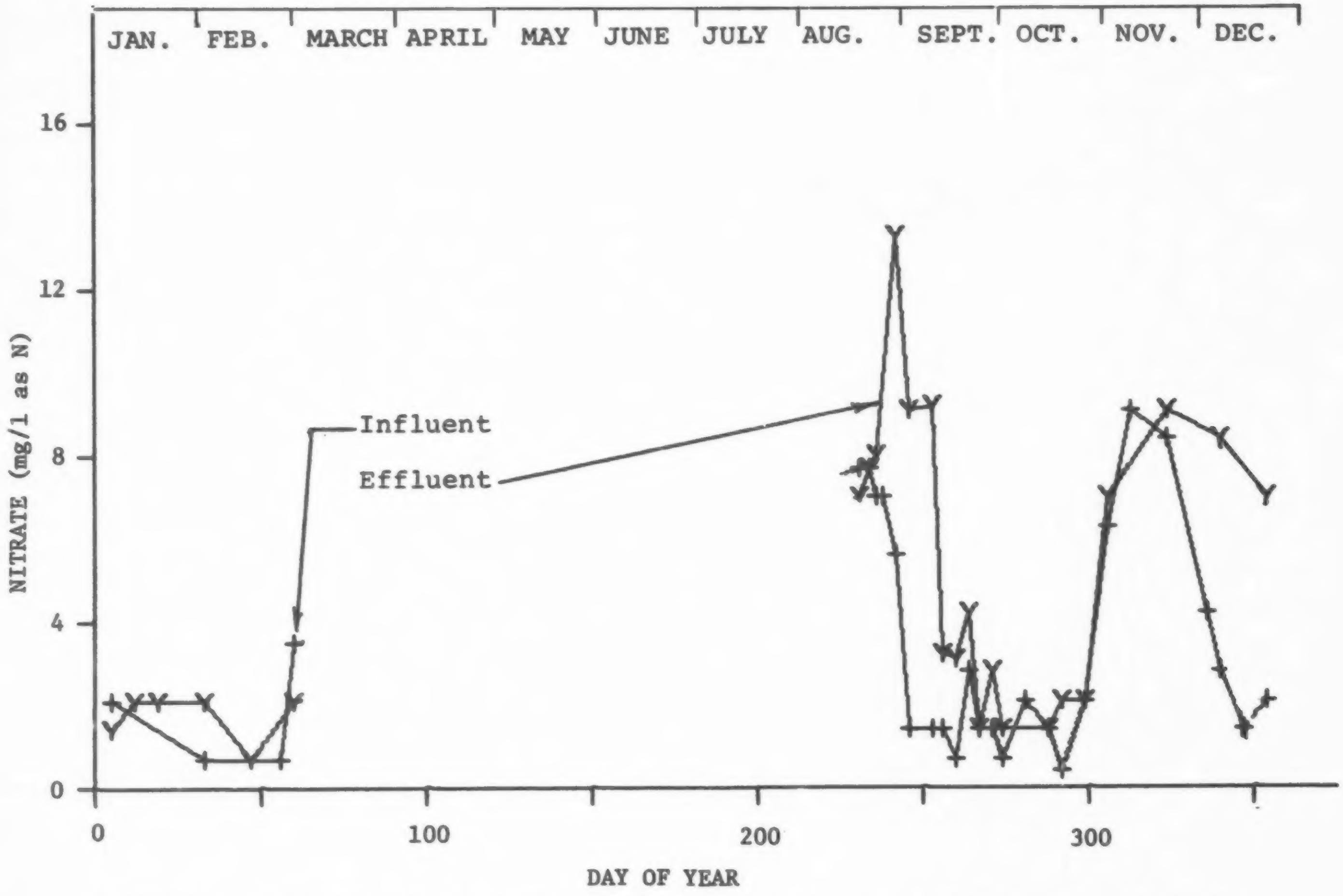


Figure 38. Influent and effluent nitrate concentrations vs. time for the RBC during the period August 1971 to March 1972.

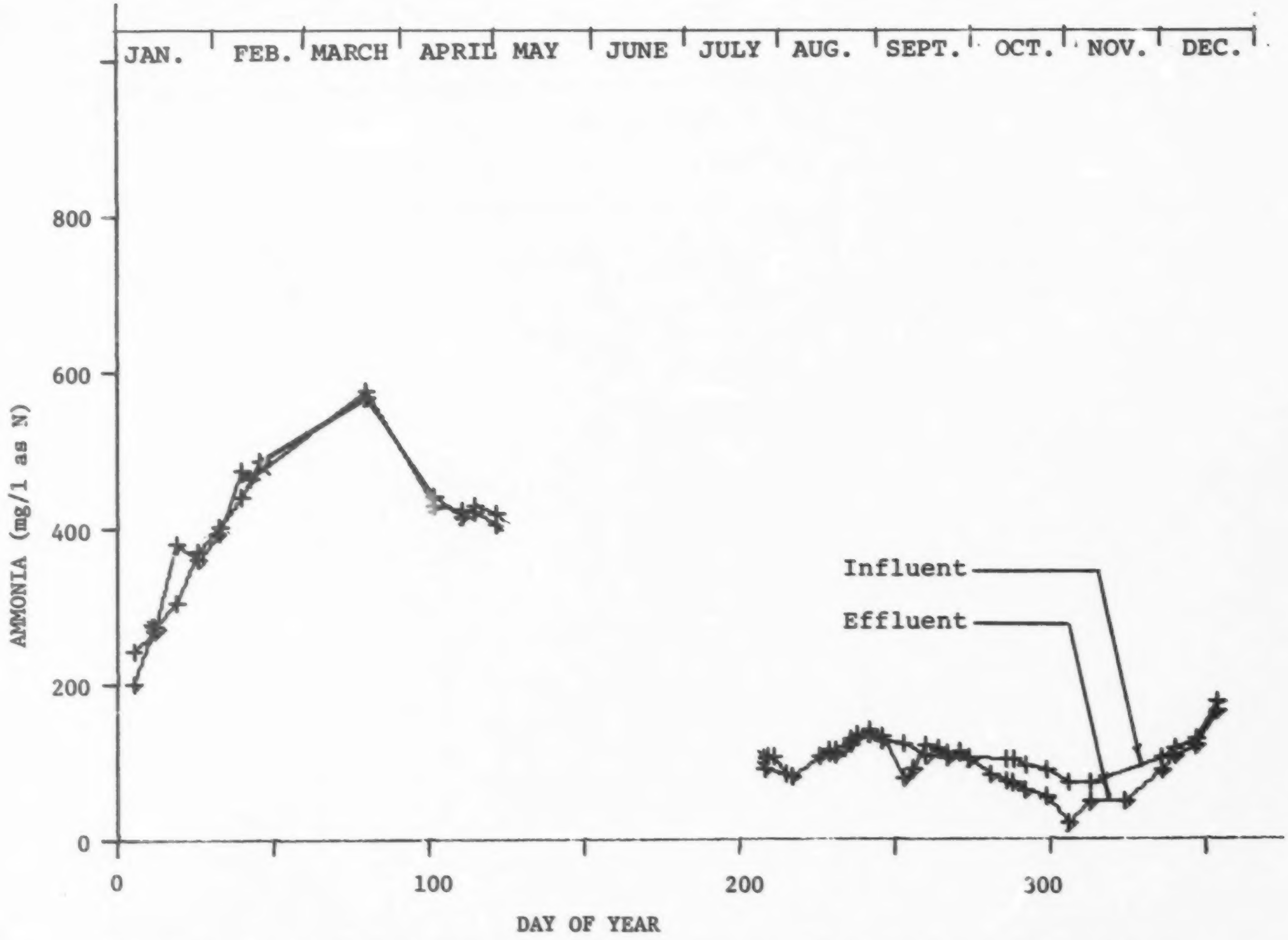


Figure 39. Influent and effluent ammonia concentrations vs. time for the RBC during the period July 1971 to May 1972.

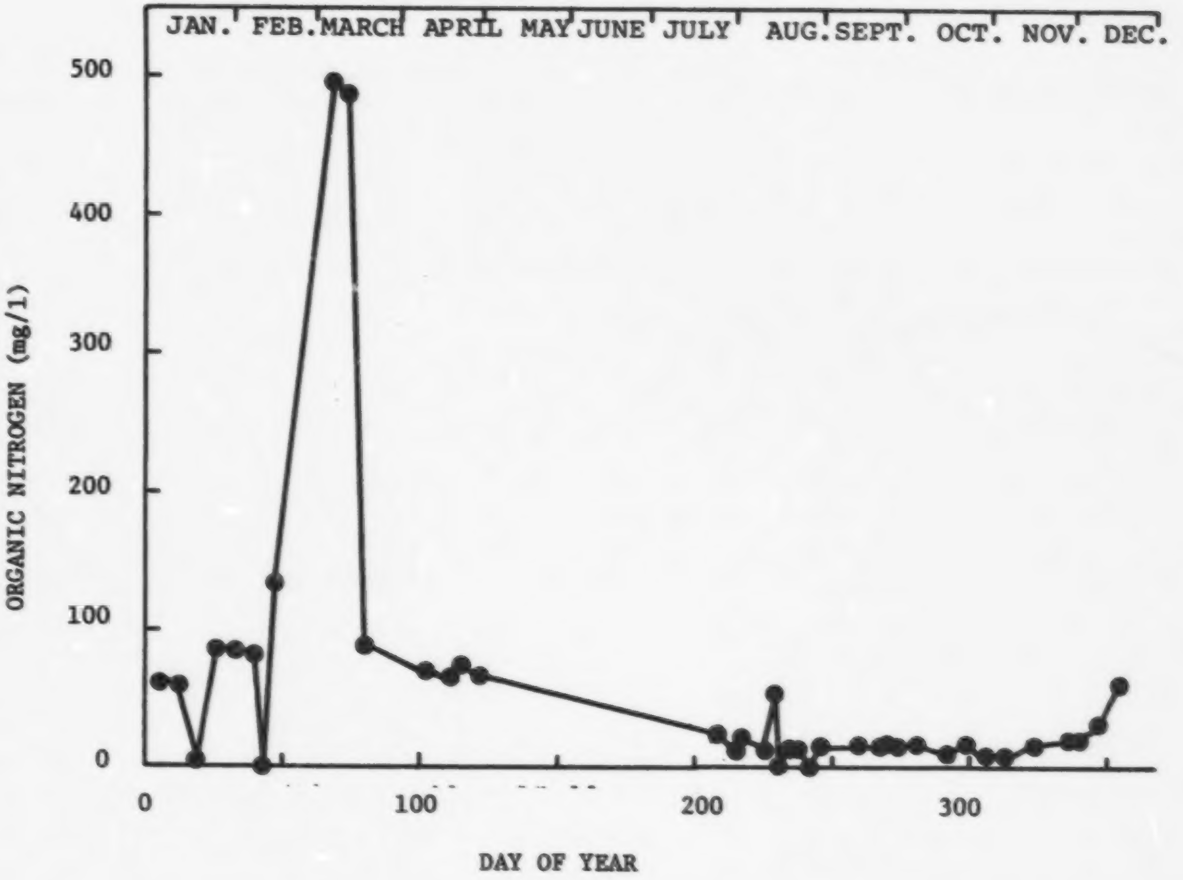


Figure 40. Influent and effluent organic nitrogen concentrations vs. time for the RBC effluent for the period July 1971 to May 1972.

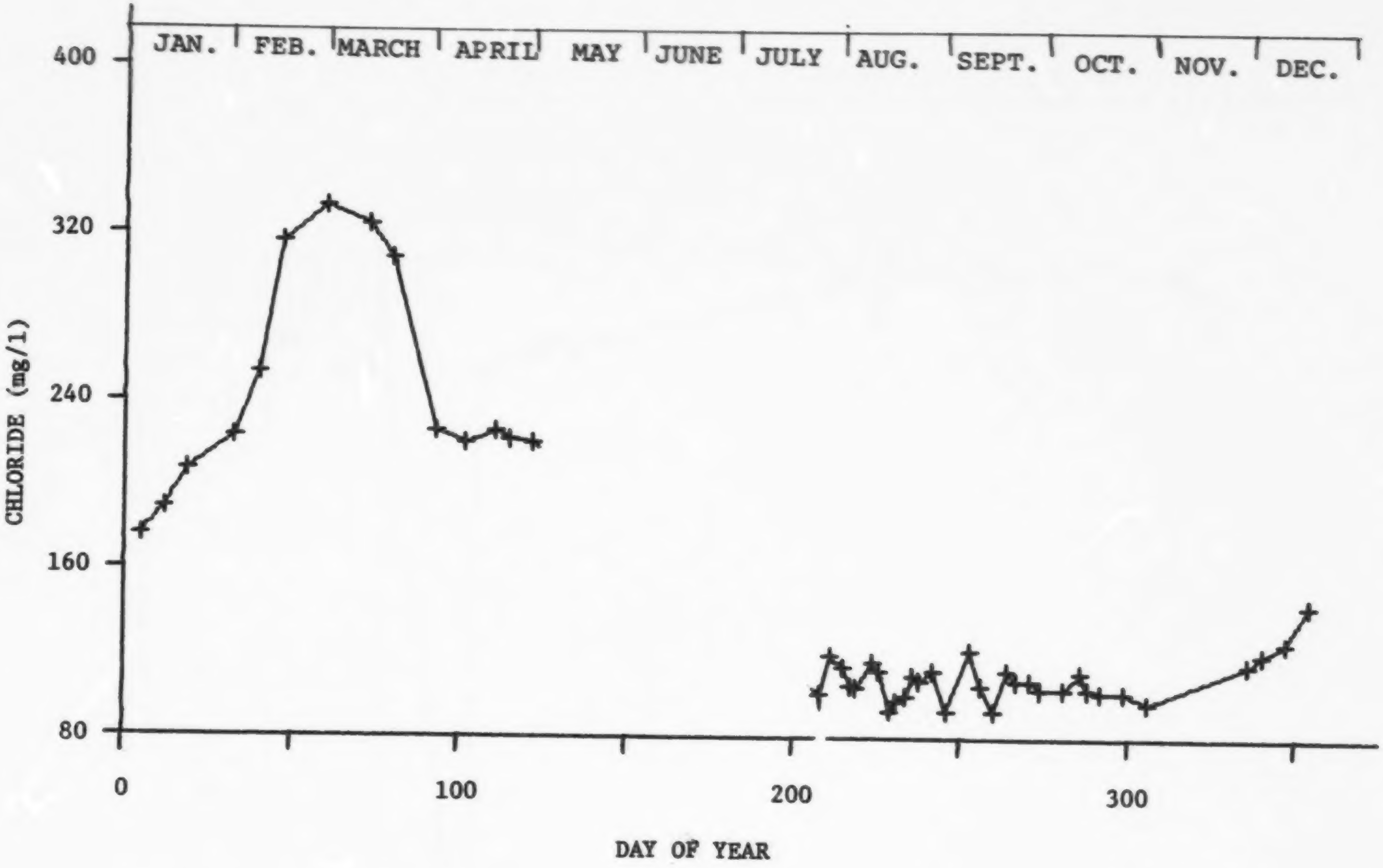


Figure 41. Influent chloride concentrations vs. time for the RBC during the period July 1971 to May 1972

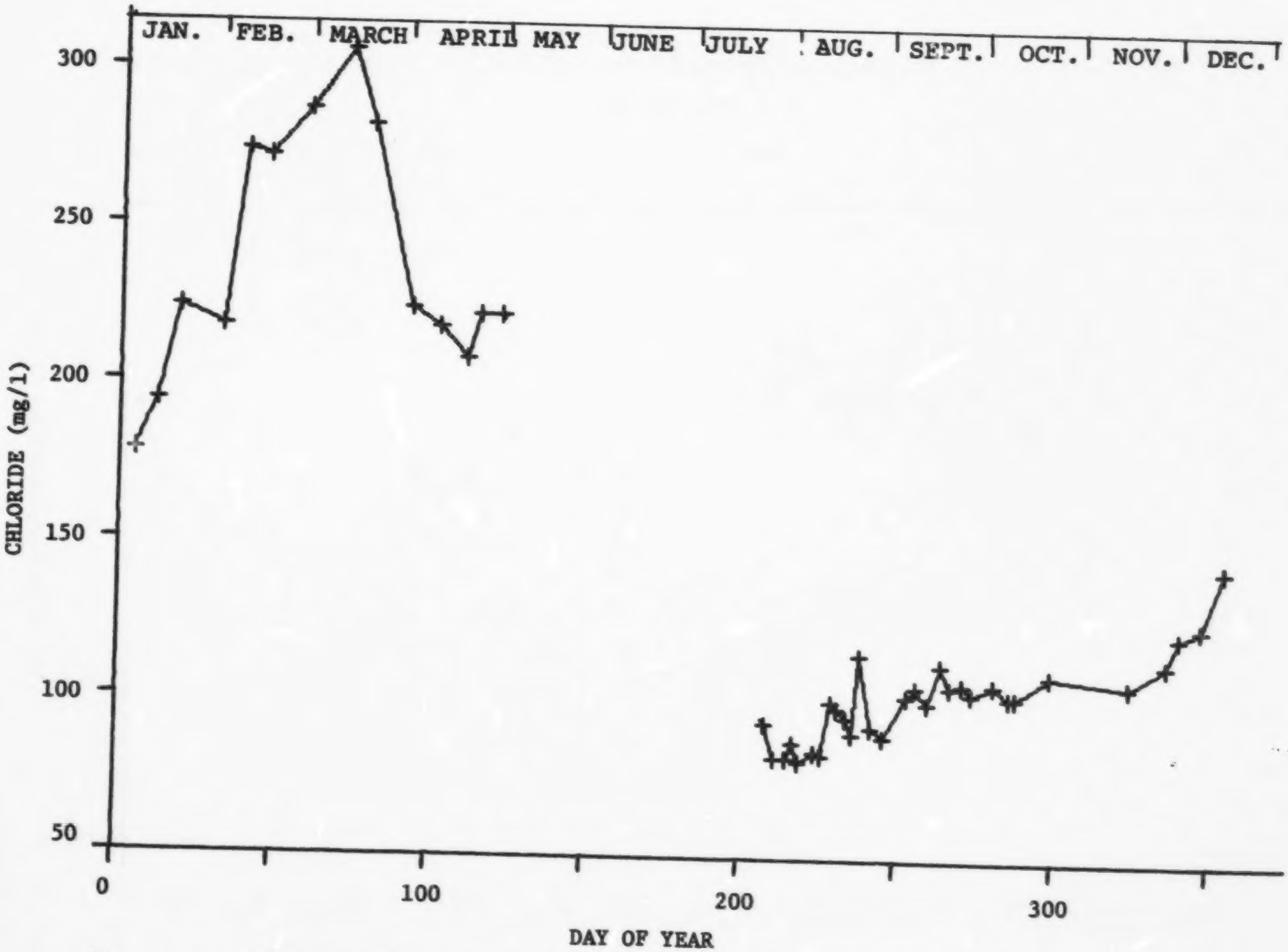


Figure 42. Effluent chloride concentration vs. time for the RBC during the period July 1971 to May 1972.

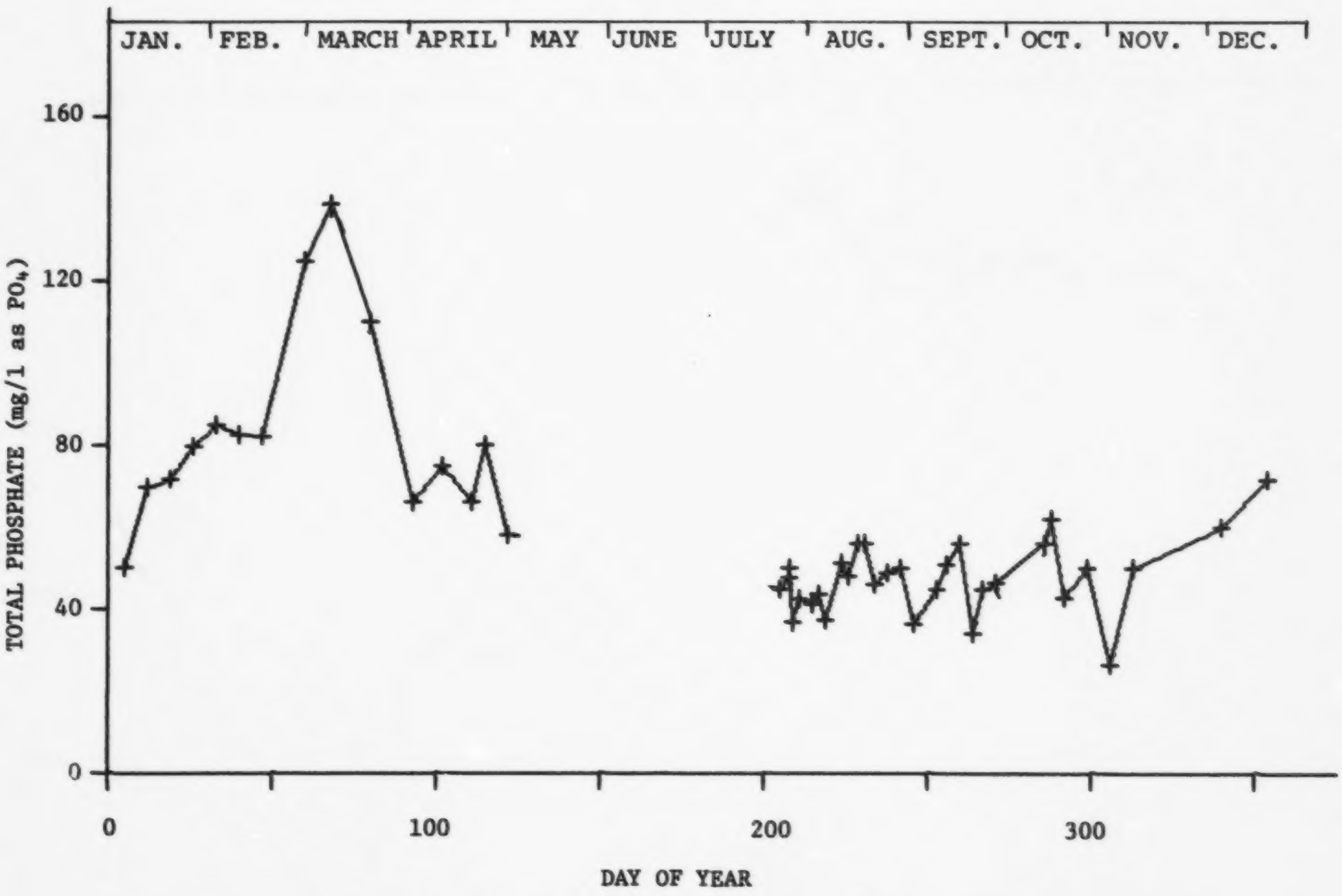


Figure 43. Influent total phosphate concentration vs. time for the RBC during the period July 1971 to May 1972.

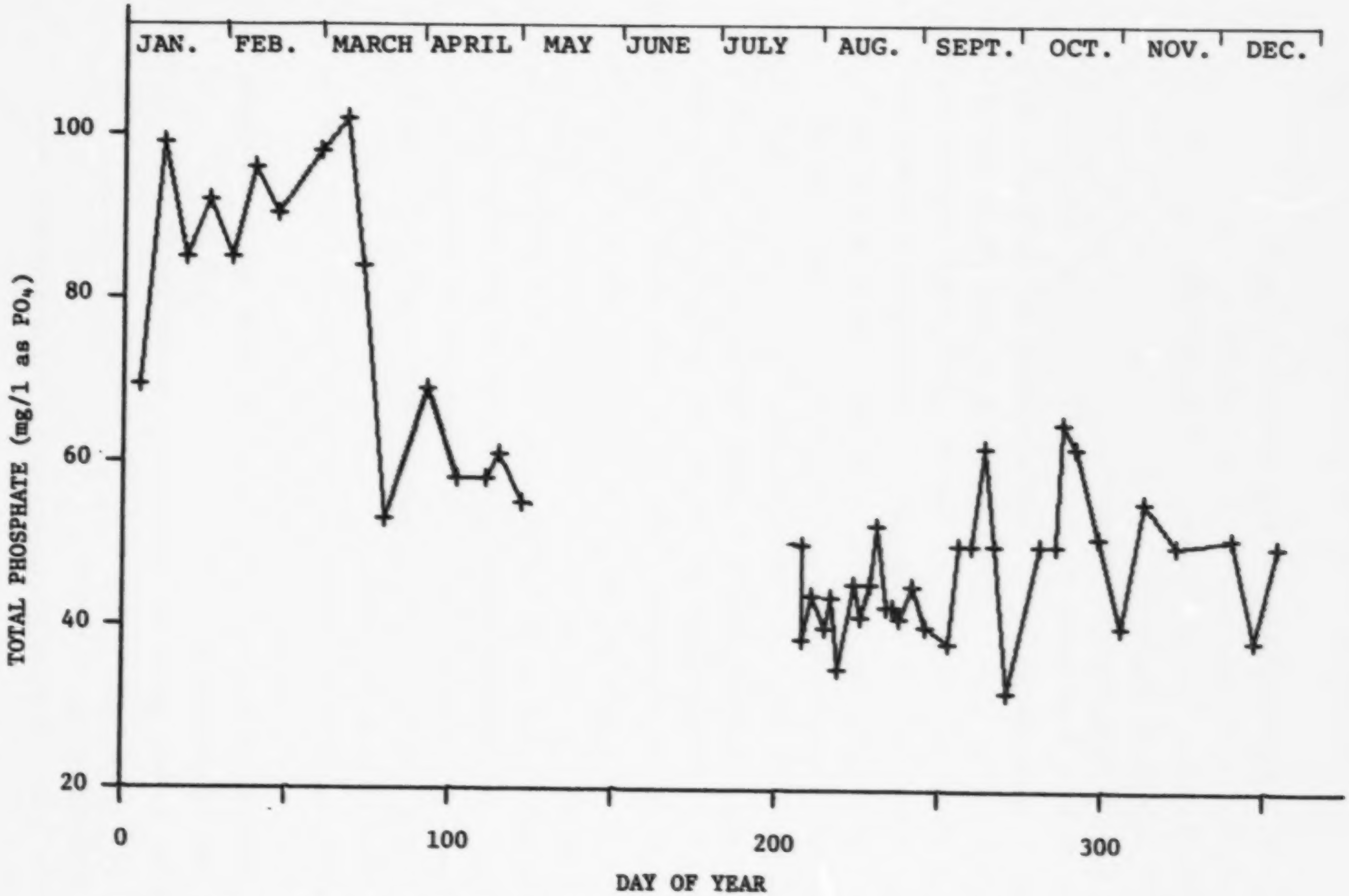


Figure 44. Effluent total phosphate concentration vs. time for the RBC during the period July 1971 to May 1972.

SECTION VI

EVALUATION OF THE ORIGINAL SYSTEM

A waste management system has four primary functions:

1. Separation of the manure from the animals.
2. Transport of the waste materials from the buildings.
3. Treatment of the manure.
4. Final disposal or utilization.

In performing these functions the system should be compatible with the environment. Water should not be contaminated beyond the point where it can be renovated for reuse. Obnoxious levels of odor should not be emitted that offend neighbors, workers, or owners. Insects and airborne diseases should be controlled. The system must be compatible with animal psychology and physiology by allowing for and taking advantage of animal habits as well as physiological limitations. Animal contact with disease organisms and toxic gases and liquids should be minimized. The waste management system should be compatible with an animal production management scheme by providing some flexibility in animal management. Labor and maintenance requirements should be minimized. Only a reasonable technical and management skill should be required to operate the system. Fixed and variable costs should be minimized.

The effectiveness of the manure separation and transport system in each of the three systems will be evaluated in terms of the following criteria.

1. The system should permit quick separation of the manure from animal contact thus removing a potential source of disease organisms or toxic materials.
2. The manure should be removed from the building thus removing a source of odors and toxic gases.
3. Minimum energy in the form of manual labor and other energy forms should be required.
4. The system should be simple in design so that it can be easily assembled from readily available materials by local skills thus minimizing construction costs.
5. It should contain few moving parts to minimize maintenance.

MANURE - ANIMAL SEPARATION

The flushing gutter system permitted quick separation of the animal from contact with his waste materials in the finishing buildings and in those farrowing buildings with pens that permitted the animal to get the full length of her body into the gutters. The hogs and pens remained clean and dry. The farrowing sows did not use the gutters as diligently as the finishing animals; however, the nursing area, sow, and baby pigs remained generally clean and dry.

The animals in the farrowing buildings with the narrower pens were not separated from their waste materials as effectively, primarily because of pen design. The animals would play in the gutter with their front feet in the gutter and deposit their waste materials 0.7-1.0 m from the gutter. This resulted in pens, sows, and baby pigs that were often damp and dirty.

Designing and constructing the pen so that the animal can get the full length of its body in the gutter is important to enable the animals to place their waste materials in the gutter. Closer confinement of the farrowing animals in farrowing stalls, for example, would insure that the wastes be placed in a known location; however, the expense of doing this for waste handling purposes may not be justified since only minimal labor was required to move the manure into the gutter.

In both the farrowing and finishing buildings, the animals were able to be in contact with the manure primarily while cleaning water was running down the gutters. One may be concerned that this water and manure running from one pen to another may spread disease. This was not a problem in any of the farrowing buildings. An outbreak of scours occurred in the finishing buildings in June, 1972. Diseased animals became dehydrated and were observed drinking the water running down the gutter. This may have been a complicating factor in the disease problem; however, there was not enough evidence to support this. Smith[23] reported an outbreak of T.G.E. in a swine finishing building. He found that virus was able to survive treatment in anaerobic lagoons. He did not present any evidence suggesting that flushing gutters complicated disease problems.

MANURE REMOVAL FROM BUILDINGS

The manure was quickly removed from the farrowing houses by treated effluent running down the gutters once the manure was placed in the gutters. Very little labor was required to keep the gutters clean. Baby pigs being flushed down the gutters seems to be no problem, especially if the pigs are over 3-5 days old.

Manure was quickly removed from the finishing houses and very little labor was required to remove the manure until the total weight of animals in the buildings was about 31,000 kg. While the total weight of animals was above this weight, two manhours per day were required to scrape the manure from the gutter. The slope of these gutters was 0.4 percent. The velocity of the water decreased as it moved down the gutter. The performance of these gutters may be improved by adding another flush tank midway down the gutter. Since the water from the second flush tank would not travel as far the velocity would be faster and better able to remove the waste materials. New flushing gutters should be constructed on a 0.8 to 1.0-percent slope to increase the velocity of water down the gutter. A 0.4-percent slope and a 570-1 flush in one minute every hour seems sufficient in farrowing buildings since the animal density is not as great.

The flushing gutters and flush tanks were easily constructed from readily available materials and could be constructed by local skills. The gutter was formed concrete. The flush tanks were ordinary stock tanks, while the dosing siphons were made of plastic pipe and plumbing parts. These materials are all easily acquired and are very simple to assemble. Except for the pumps the entire manure transport system has no moving parts. The advantage of no moving parts is best shown by the fact that the dosing siphon needed only annual cleaning after some initial modifications. The pipe that carried the manure from the buildings to the treatment device never clogged.

TREATMENT OF THE MANURE

The following criteria will be used to evaluate the effectiveness of the waste treatment systems.

1. The treatment system should minimize air and water pollution from wastes that animals produce and should conserve the use of potable water.

2. If recycled, the effluent should be easily handled by commonly available equipment, cause no obnoxious odors in or around the production buildings, contain no toxic materials or disease causing organisms, and have fluid properties that will enable it to efficiently transport the manure.
3. The waste treatment system should require minimum maintenance, labor, and technical management skill.

One of the major attributes of the aeration basin system is that the aerobic system is odorless. Insects were not a problem near this system. These attributes would make this system more acceptable near populated areas.

An aerobic lagoon was part of the lagoon aeration basin system and the RBC system. These lagoons emitted some undesirable odor from mid-April until early June. This makes these two systems undesirable near heavily populated areas, although these odors may be tolerable to the livestock producer himself. The 6-m aeration basin caused no odor problems. The RBC, on the other hand, was a constant source of odor. Insects were not a problem around either of these systems.

The excess water, from all three systems, irrigated to crop land caused no odors during application and caused no apparent damage to the corn grown in the application area. Koelliker's work[17] indicates that 95, 99$^+$, and 99$^+$ percent of the COD, ammonia-N, and total phosphate are removed after percolation through the top few inches of soil. This provides excellent water treatment with no odor problems. It would appear that this is a satisfactory method for disposing of excess water. However, more investigation is needed to determine more precisely what effect this effluent has upon crops, soil, ground water, and tile water.

The 12-m aeration basin and anaerobic lagoons were shown to be effective in removing carbonaceous materials from the swine wastes. During the first three months of operation, the 12-m aeration basin removed approximately 97 and 90 percent of the BOD$_5$ and COD, respectively, that was added. The anaerobic lagoon associated with the 6 m aeration basin removed 92 and 96 percent of the BOD$_5$ and COD respectively that was added during the entire test period July 1971 to June 1972. The RBC lagoon removed 73 and 83 percent of the BOD$_5$ and COD during the entire test period. The RBC itself removed very little oxygen demanding material. It removed 50 percent of the BOD_5 added to it from November to early December. It removed only a negligible amount of BOD_5 for the remainder of the test period.

The treated effluent returned to the swine buildings in all three systems was acceptable for use as cleaning water. No objectionable odors, or animal health problems were encountered that could be directly related to the treated effluent. Its fluid properties were such that it was able to remove manure from the gutters.

The 5-hp floating aerator functioned satisfactorily throughout the operating period. The major problem associated with the aeration basin system was the inability of the system to dependably return the high solids effluent to the flush tanks. Return lines and flow control equipment should be constructed with the smoothest, most reasonably priced material available. Also, they should contain as few constrictions and rough connections as possible, to prevent solids from clogging in the return lines. Pumps within the 1/2 to 2 hp range that can continuously pump effluent that contains hog hairs, grain hulls, manure solids, and bacteria are needed. Efficient, low cost, low maintenance pumps meeting these criteria have not yet been found.

The effluent was successfully returned to the farrowing buildings during the winter while the aerator was not operating. While manufacturers have claimed that the aerator will operate throughout the winter, it seems that the possible extra maintenance problems are not justified. During cold weather very little bacterial activity occurs thus only minimal oxidation of organic material occurs. The settled effluent that is available without aeration is satisfactory for gutter cleaning.

However, operating with no aeration during the winter with heavier manure loading should be investigated since no animals were in the farrowing buildings for nearly three months of the winter during this testing period. Manure accumulation may become a problem in the spring.

The treated effluent from the lagoon-aeration basin system was returned to the flush tanks with few problems. All that was required was to clean the pump inlet screen once or twice per week and check the flow rate to be sure the return lines were not becoming clogged. The effluent was pumped during the winter months with no problems.

Aeration of the lagoon effluent removed the odors from the lagoon effluent before it was returned to the farrowing buildings. However, it may be possible to return lagoon effluent directly to the flush tanks without causing odor problems. If undesirable odors occur, perhaps the effluent could be aerated as it enters the flush tank. The flush tank could be covered so that the odors could be vented outside the building.

Further development and operating knowledge is needed before application of the Rotating Biological Contactor for treating lagoon effluent can be recommended. While the RBC effluent was easily returned to the flush tanks, the RBC has presented several operational problems. The precipitation of calcium carbonate and perhaps magnesium ammonium phosphate caused the sump pump failures. The calcium carbonate that precipitated in the disk section had to be removed every 10-15 days from January through March. The disk drive assembly needs modification to improve chain and sprocket life. Proper loading and operating conditions for optimum BOD_5 removal need to be understood more completely. Since the RBC does not function well during the winter, provisions for bypassing the RBC must be made so that lagoon effluent can be recirculated, thus avoiding the expense of operating the RBC during the winter.

SECTION VII

SYSTEM MODIFICATIONS AND EVALUATIONS

At the end of the evaluation period, it was evident that the three waste handling and treatment systems were not entirely satisfactory. During the final stages of the project a series of system modifications were made in an effort to gain additional insight into the problems, to solve them where possible, and where solutions were not available to alter the system sufficiently so that operable systems would be intact upon completion of the project.

Toward the end of the evaluation period, the station suffered an increase of scours within the herd. Although there are no data to implicate the flushing gutter in causing the disease, the presence of flushing water did seem to contribute to more rapid and widespread infection. Treatment of infected hogs was also complicated because they had a source of non-medicated water available to them.

AERATION BASIN SYSTEM

At the time of the summer farrowing in June and July 1972, treated wastewater was being used to flush the gutters. Although pumping problems were occurring, the system was operable and no appreciable disease problems were encountered. Prior to the fall farrowing, however, enteric disease, dysentery, problems had become sufficiently severe in the finishing building that the station personnel elected to use fresh water to flush the gutters. An overflow conduit from the aeration basin carried excess water to a previously existing storage lagoon on the station property. Bedding was used in the farrowing buildings for the February-March 1973 farrowing and the aeration basin was diverted to an evaluation of an induced aspiration aeration device.

Induced Aspiration Aeration Device

In an effort to overcome the inherent problems of surface aerators during freezing conditions an induced aspiration aerator was obtained for evaluation from Fairfield Engineering and Manufacturing Company, Fairfield, Iowa. The purpose of the study was to determine if an Aerob-A-Jet could be successfully operated when unprotected throughout the winter. The criteria for success were to maintain temperature and dissolved oxygen concentrations at a level that continued some detectable biological degradation of the waste.

The Aerob-A-Jet is a floating surface aerator that pulls air down into the liquid and disperses it as fine bubbles. A hollow shaft turns a boat propeller, forcing the liquid vertically down. The vortex formed at the propeller pulls air through this hollow shaft where it is broken into small bubbles and forced downward. The oxygen transfer efficiency of this method of aeration is claimed to be comparable to, or even better than, that of conventional surface aerators. This aerator also has the merit of pulling air past the motor where it picks up heat which is largely transferred to the water. A drawing of this aerator is shown in Figure 45.

Similar aeration devices have been used for some time as stationary units in underfloor oxidation ditches for swine confinement buildings. In this situation, where heat losses are small, stable liquid temperatures have been maintained in the thermophilic range of 40° C to 50° C throughout the winter without the addition of supplemental heat to the liquid.

In early November of 1972 an Aerob-A-Jet was installed in the 12-m diameter by 3 m deep concrete aeration basin. There was a constant level overflow from this basin into the small anaerobic lagoon of the lagoon-aeration basin system. Final disposal then took place from this lagoon. At the time of installation, the farrowing units were unoccupied.

Since no farrowing activity was expected between November, 1972, and February, 1973, it was decided to load this basin with frequent additions of finishing hog slurry from two different types of slurry storage on the farm. One was a large pit into which the manure from a finishing building was flushed with fresh water. The liquid portion then overflowed into a large lagoon whereas the solids settled in the pit. The other storage was a shallow pit beneath the slatted floor of a small finishing building. When weather permitted, 3 m^3 loads were transferred to the aeration basin in a liquid manure tank. Samples were taken of the slurry and the mixed liquor from the aeration basin before the loading and within 6 to 24 hrs after the addition. The dissolved oxygen content and temperature of the water were measured before and after addition of slurry. In December, a thermograph was installed to continuously record liquid and air temperatures. With this, the changes in temperature attributable to the additions of the slurry could be noted in more detail.

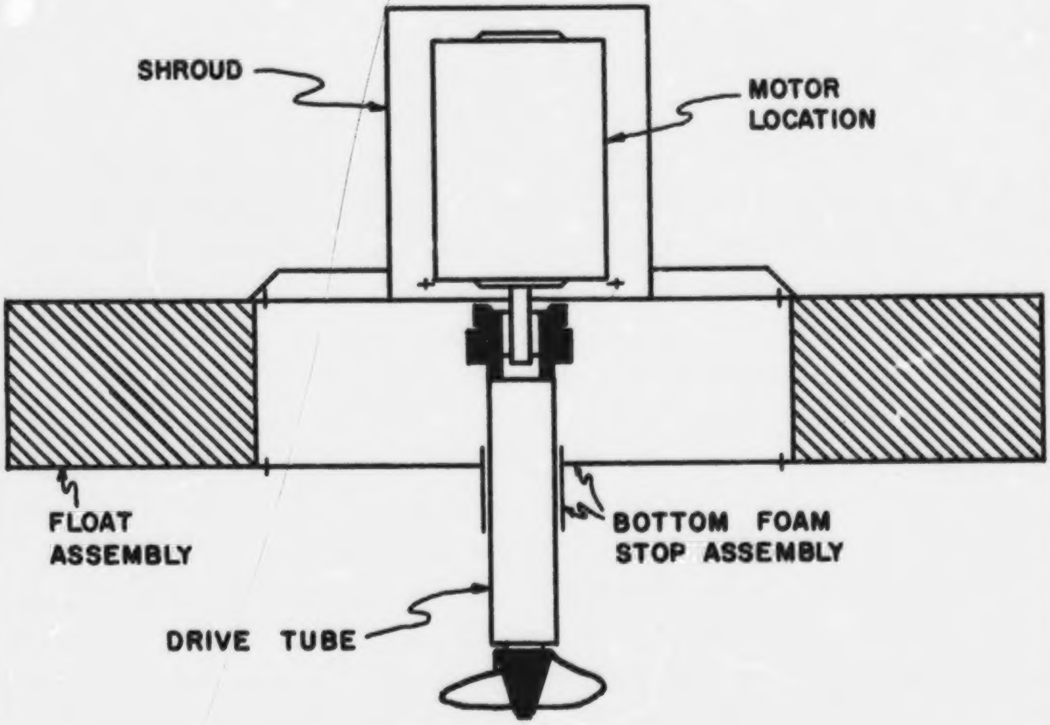

SHROUD
MOTOR LOCATION
FLOAT ASSEMBLY
BOTTOM FOAM STOP ASSEMBLY
DRIVE TUBE

Figure 45. The aerator used for the period November 1972 to June 1973.

The first problem encountered was the weather. At temperatures below -7° C, the slurry wagon would not function properly. Also, it required three or four warm days to thaw the slurry under the slatted floor sufficiently for it to be pumped. Therefore, the loading interval was sporadic.

A considerable amount of foaming was observed. Foam formation correlated well with the loading, i.e., just after loading, foam would build up rapidly and then slowly recede over the following day or two. At times, there were more than 1 m of foam covering the basin.

The temperature data tend to show that, with a continuous feed of waste into this basin, a liquid temperature in the range of 7 to 10° C could be maintained throughout the winter. Two records from a temperature recorder started just before loading the basin and operated continuously until a few hours after a second loading are shown in Figure 46. Preliminary indications were that there is an immediate temperature rise due to the loading that diminishes over the following 48-hr period. The data do not show conclusively how much of the heating effect was due to the loading and how much was due to transfer from the surrounding air. This merits further study.

The samples taken from the feed slurry and aeration basin were evaluated for COD, BOD_5, and total and suspended solids. The results of these tests appear in Tables 10 and 11. The COD of the basin is shown graphically in Figure 47. There is a definite degradation of the COD between loadings. The BOD shows the same trends. Extended aeration at a reduced BOD loading and resultant long aeration time compensates for the low metabolism rate of microorganisms.

Except for when the aerator was inoperable with a sheared pin, the surface of the basin was largely free of ice. Some ice did form around the perimeter during the coldest days. If the basin had been fed with wastes on a uniform, continuous basis, ice formation might have been entirely prevented.

The dissolved oxygen content of the basin remained at or near saturation the entire winter. The 3-hp motor on the aerator supplied more than sufficient aeration power capacity for the light loading received. Because of this aerobic state throughout the winter, there was little or no odor escaping from this system.

In summary, the induced aspiration-type floating aerators did indeed maintain an aeration basin saturated with oxygen and nearly ice-free throughout the winter. With sufficient waste material fed into the basin, it should

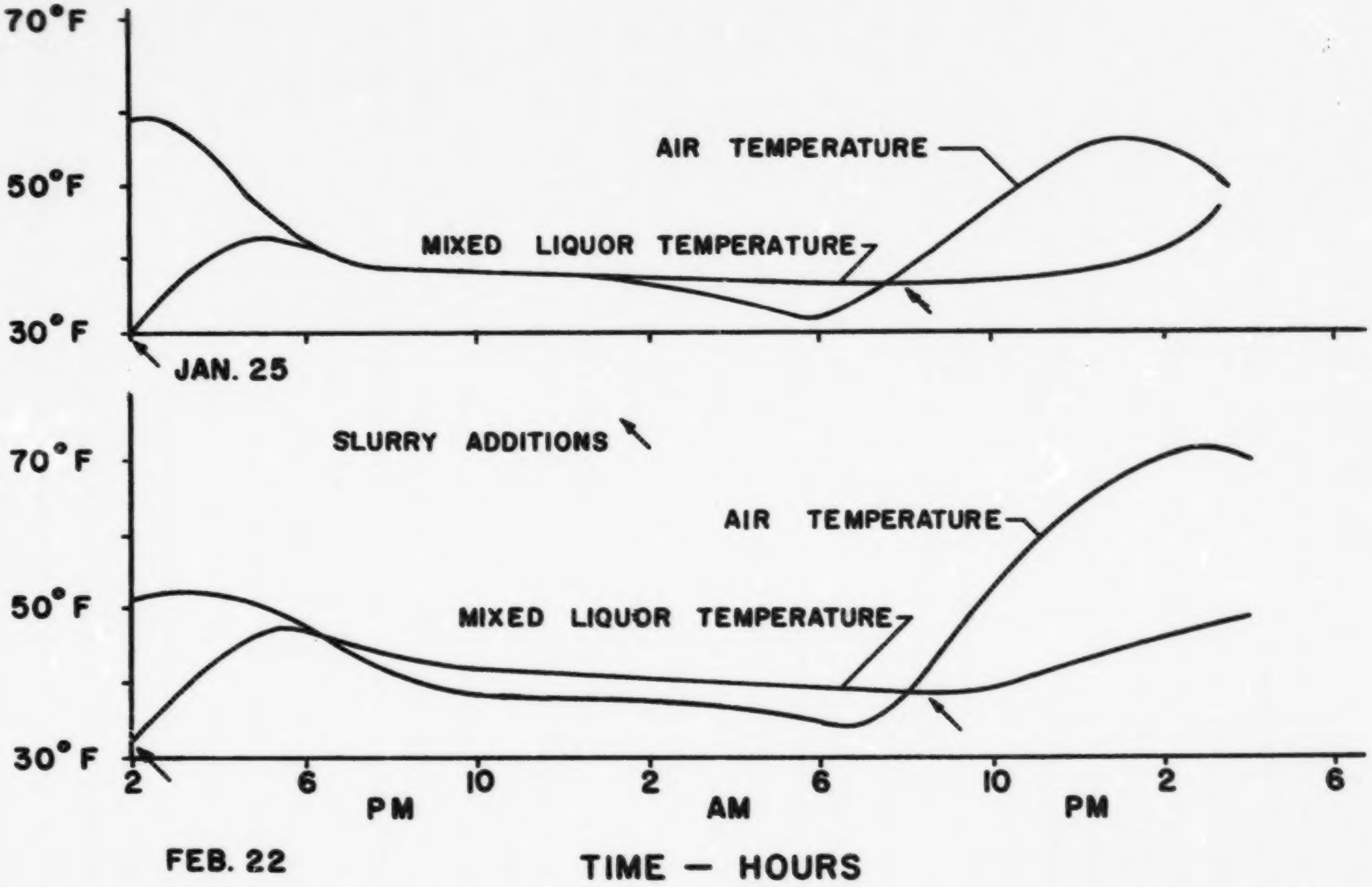


Figure 46. Temperature vs. time for the mixed liquor in the aeration basin and of the surrounding air. The time period covered in each case is from immediately before an addition of waste slurry to a few hours after a second addition.

Table 10. STRENGTH OF WASTE ADDED TO THE AERATION BASIN DURING THE AEROB-A-JET STUDY (mg/l).

Date	Waste added, m^3	COD	BOD	Total solids	Suspended solids
Nov. 21	3	80,000	10,150	-	11,000 6,520[a]
Dec. 15	6	140,000	30,000	161,200 129,900[a]	26,000 15,000[a]
Dec. 19	6	45,000	6,750 3,150[a]	35,820 30,000[a]	7,050 4,020[a]
Dec. 28	6	200,000	27,750	121,900 90,300[a]	37,000 23,800[a]
Jan. 3	6	115,000	17,800	87,390 71,250[a]	11,560 6,200[a]
Jan. 25	3	55,200	10,600	55,760	5,920 2,320[a]
Jan. 26	21	171,000	61,000	180,000 135,960[a]	47,640 30,240[a]
Feb. 22	10	76,800	23,200	56,520 43,080[a]	9,120 4,800[a]
Feb. 23	15	65,660	34,600	82,360 57,000[a]	24,120 12,080[a]

[a] Notes: volatile portion.

Table 11. STRENGTH OF WASTE IN THE AERATION BASIN DURING THE AEROB-A-JET STUDY(mg/1).

	Before loading				After loading			
Date	COD	BOD	Total solids	Suspended solids	COD	BOD	Total solids	Suspended solids
Nov. 3	360	100	-	-	-	-	-	-
Nov. 15	109	20	1,420 340[a]	1,340 292[a]	-	-	-	-
Nov. 21	125	17	1,740 570[a]	1,310 248[a]	340	>100	1,810 605[a]	1,350 280[a]
Dec. 15	-	-	-	-	1,300	-	3,040 1,270[a]	2,250 670[a]
Dec. 19	-	-	-	-	1,120	680	2,675 1,123[a]	2,150 670[a]
Dec. 28	500	130	1,950 530[a]	1,760 360[a]	1,320	460	2,600 1,030[a]	2,120 1,020[a]
Jan. 3	680	190	2,028 648[a]	1,760 412[a]	200	280	2,116	1,884
Jan. 25	-	-	-	-	1,060	340	2,104 772[a]	1,696 432[a]
Jan. 26	1,060	340	2,104 772[a]	1,696 432[a]	2,665	1,360	4,204 2,172[a]	2,592 1,008[a]
Feb. 22	-	-	-	-	1,440	445	2,364 1,032[a]	1,812 624[a]
Feb. 23	1,440	445	2,364 1,032[a]	1,812 624[a]	1,460	700	2,764 1,312[a]	1,956 744[a]

[a] Notes: volatile portion.

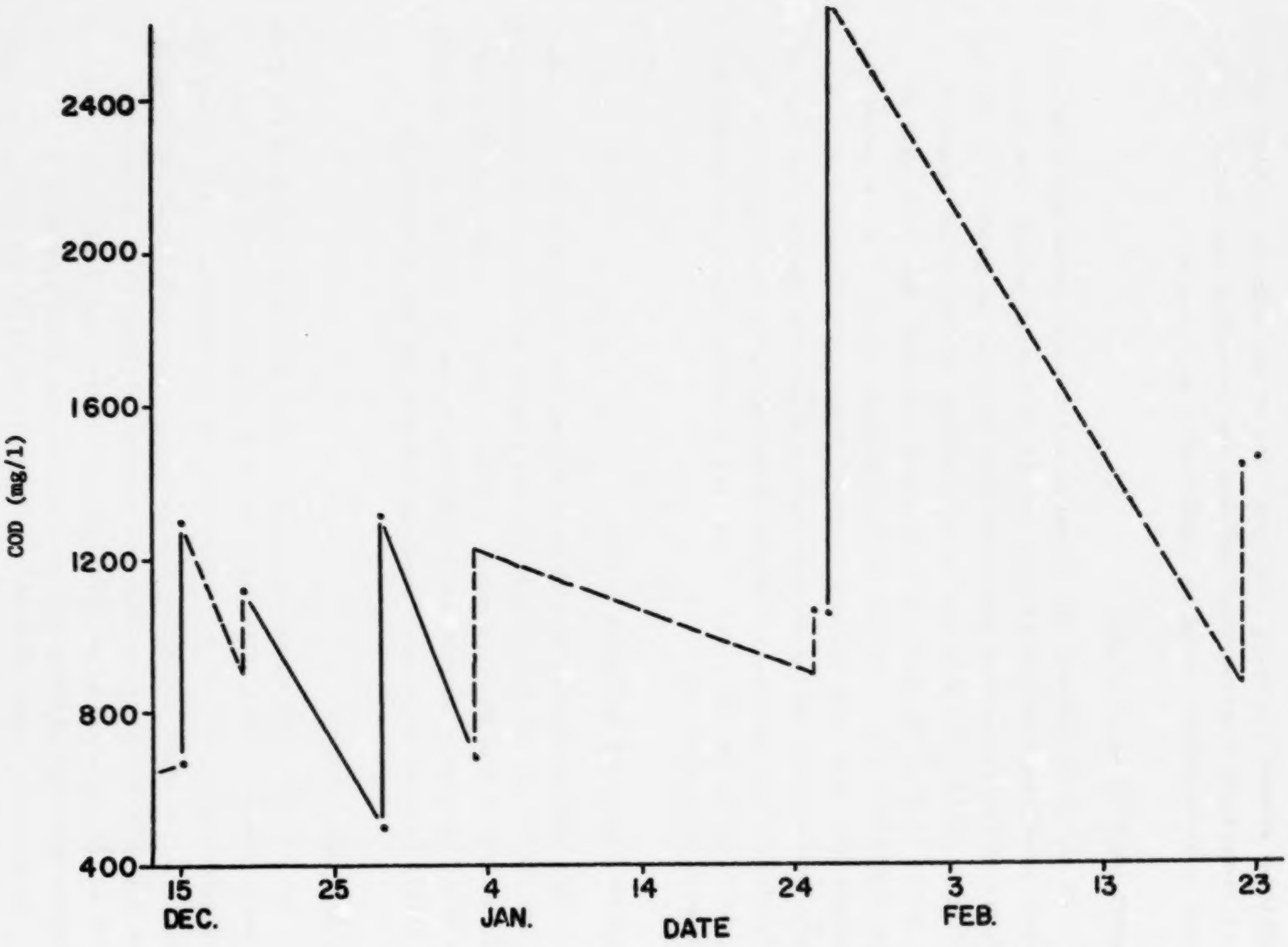


Figure 47. COD vs. time of the mixed liquor in the basin during the Aerob-A-Jet study.

be possible to maintain a liquid temperature near 9° C and achieve some continued aerobic biological activity. Any spring start-up problem associated with re-aerating a system which had been fed throughout the winter, but allowed to go anaerobic, would be significantly ameliorated.

LAGOON-AERATION BASIN SYSTEM

Of the three systems, the lagoon aeration basin system presented the fewest operational difficulties during the evaluation period. The shortcomings of the system were associated more with the pen geometry in the farrowing buildings than with the manure flushing and biological treatment. As in the case of the aeration basin system, however, not being able to find a suitable pump to handle the return liquor reliably was an added inconvenience. When pump failure occurred, fresh water flushing had to be used, thus aggravating the storage problem within the system. The fear of a breakout of the dysentery disorder in the farrowing buildings ended use of the flush system and a return was made to traditional straw bedding for the March, 1972, farrowing.

ROTATING BIOLOGICAL CONTACTOR SYSTEM

The rotating biological contactor system, although successful in terms of hog production and manure removal, was plagued with operating difficulties attributable to the RBC unit and to a severe enteric disease that infected the herd. The modifications and studies described in this section represent an effort to respond to these problems and overcome the difficulties.

RBC Flow Rate Studies

The RBC unit when operating properly had a grey-brown slime on the disks. By early summer of 1972, this slime had been largely replaced by a black crystaline substance. In this condition, the RBC provided little if any BOD reduction. In order to improve its performance the feed supply was changed from lagoon effluent to the less concentrated effluent from the aeration basin of the lagoon-aeration basin system. Under these conditions, an acceptable appearing slime growth developed on the disks by August 1.

On August 4, lagoon effluent was again diverted to the RBC but at lower flow rates. The data presented in Table 12 were generated. These data do indicate improved performance as a result of the combined low flow rates and revitalized slime growth. Mechanical difficulties continued to make routine operations difficult and on September 15, 1972, the RBC unit was drained and permanently removed from service. The piping system was altered so that the RBC was bypassed and flushed with water pumped directly from the anaerobic lagoon. This water has been used as the flushing water source since then. This procedure has resulted in significantly fewer daily maintenance problems.

Table 12. RBC PERFORMANCE UNDER VARIOUS FLOW RATES AFTER REVITALIZATION.

Date	August 9	August 16	August 24	September 7
Flow rate (1 per min.)	37	19	37	37
COD				
influent (mg/1)	2450	2350	2870	2530
effluent (mg/1)	2100	1150	2280	2040
percent removal	14	51	21	19

Chlorination of Flush Water

In response to the continued problems with vibrionic dysentery, chlorination of the flush water was initiated to evaluate its effectiveness. A 13-percent solution of sodium hypochlorite was used as the chlorine source. The chlorine residual was maintained at 1 to 5 mg/l. Continual monitoring was necessary to maintain this level. The effect of chlorination was inconclusive. The outbreaks of dysentery became less frequent but this may have been attributable to the hogs reaching sufficient size to have increased resistance to the infection. Further evaluation with the subsequent group of hogs was thwarted by failure of the chlorine feed pump. The cost of this chlorine treatment was approximately two cents per hog per day or an equivalent of $2.40 per pig raised.

Flushing Gutter Modifications

Again, in response to the disease problems the flushing channels in two of the finishing buildings were remodeled. This remodeling entailed removing the floor of the flushing channel and increasing its depth to provide a sloping gutter from 20 to 50 cm deep. The gutters were then covered with slats, one third of which were plastic and the remainder aluminum. Larger flush tanks were also installed at this time. The revised gutter system is shown in Figure 48.

The first group of hogs were put in this building in early June 1972. The pens stayed relatively clean and the gutters flushed effectively. Some manual scraping of pens was required to move manure to the slotted area. The disease problem which had been present previously continued to recur in isolated pens. However, treatment with medicated drinking water was easier since the pigs did not have access to an alternative source of water.

IRRIGATION SYSTEM

In order to provide sprinkler irrigation disposal of excess liquid wastes a system is being constructed which utilizes the existing large shallow lagoon (150 m by 90 m by 1.2 m) receiving the drainage from the entire station as well as overflow from the anaerobic lagoon.

The design includes a self-propelled, cable-guided, big-gun sprinkler. A stationary,electrically driven, centrifugal pump pulls water from the lagoon, discharging it into a buried 10-cm PVC main to a riser. The riser, in turn, supplies the reel-wound house connected to the central pivot of the travelling gun. The gun travels a length of 400 m in 24 hours and has a design distribution radius of 60 m. Thus, the waste can be applied to an area of approximately 6 ha.

The logic of the disposal system design was developed from: the expected volume and nutrient content of lagoon water to be disposed of; the cropping practices on the disposal area; the amount of system management that could be expected from operating personnel; and the probable climatic periods acceptable to sprinkler disposal. Nutrient

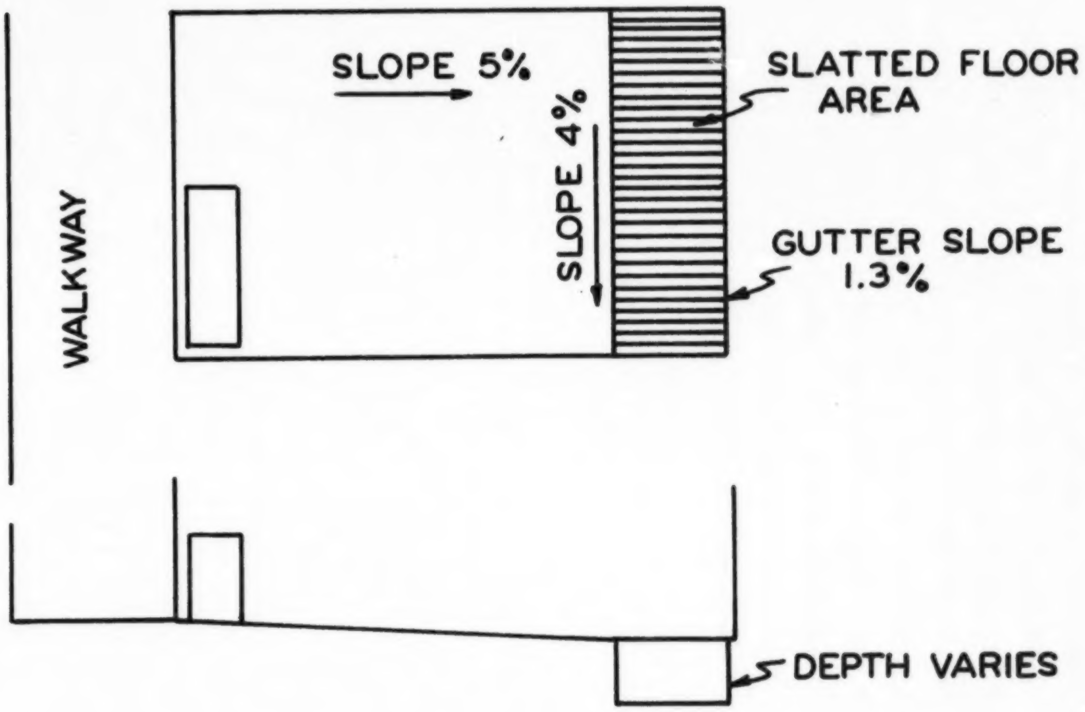

SLOPE 5%
SLOPE 4%
SLATTED FLOOR AREA
GUTTER SLOPE 1.3%
WALKWAY
DEPTH VARIES

Figure 48. Revised flushing gutter and slat arrangement used in two finishing buildings.

utilization, particularly phosphorus, indicated the total land area needed should be about 18 ha. (1 ha./250 animals) if the station operates at its full animal capacity. Climatic conditions, cropping practices, and available storage determined the application rate and frequency of about 2.5 cm per hr., 3 times each year - April, June, and October. The remainder of the design was then the matching of these requirements to obtainable equipment, economics, and management considerations. The actual quantities of nutrients applied in the first year of operation will be monitored. If the loadings exceed current guidelines for N and P application rates then adjacent blocks of 6 ha. can be used in subsequent years, thus average annual loadings will not exceed guidelines. Additional mains and risers will not be provided until field data is available to justify their installation.

SECTION VIII

REFERENCES

1. Laycock, G. E. The Immaculate Pig. The Farm Quarterly. 2(1):57-59, 133-135. 1947.

2. Hughes, F. F. Does Multiple Farrowing Pay? The Farm Quarterly. 12(1):44-45, 99-104. 1957.

3. Heitman, J., Jr., C. F. Kelly, and T. E. Bond. Ambient Air Temperature and Weight Gain in Swine. Jour. Animal Sci. 17:62-67. 1958.

4. Hazen, T. E. and D. W. Mangold. Functional and Basic Requirements of Swine Housing. Agr. Engr. 41:585-590. 1960.

5. Mangold, D. W., V. C. Speer, E. P. Taiganides, and T. E. Hazen. Interacting Factors Associated with Confinement Housing of Growing-Finishing Swine. Journal Paper No. J-4839 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Presented at the Mid-Central Region Meeting of the American Society of Agricultural Engineers, St. Joseph, Missouri. April 1964.

6. Willrich, T. L. Primary Treatment of Swine Wastes by Lagooning. In: Management of Farm Animal Wastes (Proceedings, National Symposium). Amer. Soc. Agr. Engr. pp. 70-74. 1966.

7. Taiganides, E.P., E. R. Baumann, H. P. Johnson, and T. E. Hazen. Anaerobic Decomposition of Hog Wastes. Jour. Agr. Engr. Res. 8:327-333. 1963.

8. Knight, R. S. Performance of a Cage Rotor in an Oxidation Ditch. Unpublished M.S. Thesis. Iowa State University Library, Ames. 83 pp. 1965.

9. Taiganides, E. P. and T. E. Hazen. Properties of Farm Animal Excreta. Trans. Amer. Soc. Agr. Engr. 9:374-376. 1966.

10. Merkel, J. A. Atmospheric Composition in an Enclosed Swine Production Building. Unpublished Ph.D. Thesis. Iowa State University Library. 1967.

11. Smith, R. J. Manure Transport in a Piggery Using the Aerobically Stabilized Dilute Manure. Unpublished M.S. Thesis. Iowa State University Library, Ames, Iowa. 99 pp. 1967.

12. Smith, R. J., T. E. Hazen, and J. R. Miner. Manure Management in a 700 Head Swine-Finishing Building; Two Approaches Using Renovated Waste Water. In: Livestock Waste Management and Pollution Abatement (Proceedings International Symposium of Livestock Wastes). Amer. Soc. Agr. Engr. pp. 149-153. 1971.

13. Person, H. L. and J. R. Miner. A Dosing Siphon for Discharging Cleaning Water into Flushing Gutters. Unpublished paper presented at the Mid-Central Region Meeting of the American Society of Agricultural Engineers, St. Joseph, Missouri, (Mimeo). Iowa State University, Department of Agricultural Engineering, Ames, Iowa. 11 pp. April 16, 17, 1971.

14. Koelliker, J. K. Soil Percolation as a Renovation Means of Livestock Lagoon Effluent. Unpublished M.S. Thesis. Iowa State University Library, Ames. 108 pp. 1969.

15. Vanderholm, D. H. Field Treatment and Disposal of Livestock Lagoon Effluent by Soil Percolation. Unpublished M.S. Thesis. Iowa State University Library, Ames, Iowa. 62 pp. 1969.

16. Koelliker, J. K., J. R. Miner, C. E. Beer, and T. E. Hazen. Treatment of Livestock-Lagoon Effluent by Soil Filtration. In: Livestock Waste Management and Pollution Abatement (Proceedings, International Symposium on Livestock Wastes). Amer. Soc. Agr. Engr. pp. 329-333. 1971.

17. Koelliker, J. K. and J. R. Miner. Use of Soil to Treat Anaerobic Lagoon Effluent; Renovation as a Function of Depth and Application Rate. Trans. Amer. Soc. Agr. Engr. 13:496-499. 1970.

18. Antonie, R. L. and F. M. Welch. Preliminary Results of a Novel Biological Process for Treating Dairy Wastes. Purdue University, Engineering Extension Department, Bulletin 135:115-126. 1969.

19. Welch, F. M. Preliminary Results of a New Approach in the Aerobic Biological Treatment of Highly Concentrated Wastes. Purdue University Engineering Extension Department. Bulletin 135:428-437. 1968.

20. Joost, R. H. Systemation in Using the Rotating Biological Surface (RBS) Waste Treatment Process. Purdue University, Engineering Extension Department, Bulletin 135:365-373. 1969.

21. Borchardt, J. A. Biological Waste Treatment Using Rotating Discs. In: Raymond P. Canale (ed.) Biological Waste Treatment. Wiley and Sons, Inc., New York. pp. 131-140. 1971.

22. Hultgren, J. P. Photographic Studies of the Dunging Behavior of Pigs in Confinement. Unpublished M.S. Thesis. Iowa State University Library, Ames, Iowa. 129 pp. 1971.

23. Smith, R. J. A Prototype System to Renovate and Recycle Swine Wastes Hydraulically. Unpublished Ph.D. Thesis. Iowa State University Library, Ames, Iowa. 176 pp. 1971.

24. Laursen, E. M. Sediment-Transport Mechanics in Stable Channel Design. Trans. Amer. Soc. Civil Engr. 23:195-206. 1958.

25. Ferguson, J. F. The Precipitation of Calcium Phosphates from Fresh Waters and Waste Waters. Ph.D. Thesis. Stanford University. (Mic. 70-18, 403, University Microfilms, Ann Arbor, Michigan). 194 pp. 1970.

26. Welch, F. M. New Approach to Aerobic Treatment of Wastes. Water and Waste Engr. 6(7):D12-D15. 1969.

27. Standard Methods for the Examination for Water and Wastewater. 12th ed. American Public Health Association. New York, New York. 1965.

28. Bremner, J. M and D. R. Kenney. Steam Distillation of Ammonium, Nitrate, and Nitrite. Anal. Chem. Acta 32:485-495. 1965.

29. Murphy, J. and J. P. Riley. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. Anal. Chem. Acta. 27:31-26. 1962.

SECTION IX

PUBLICATIONS AND PATENTS

1. Person, H. L. and J. R. Miner. A Dosing Siphon for Discharging Cleaning Water into Flushing Gutters. Unpublished paper presented at the Mid-Central Region Meeting of the American Society of Agricultural Engineers, St. Joseph, Missouri, April 16 and 17, 1971. (Mimeo). Iowa State University, Department of Agricultural Engineering, Ames, Iowa. 11 pp. 1971.

2. Person, H. L. and J. R. Miner. An Evaluation of Three Hydraulic Manure Transport Systems, Including a Rotating Biological Contactor, Lagoons, and Surface Aerators. In: Waste Management Research (Proceedings of the 1972 Cornell Agricultural Waste Management Conference). pp. 271-288. 1972.

3. Person, H. L., J. R. Miner, T. E. Hazen, and A. R. Mann. A Comparison of Three Systems for Transport and Treatment of Swine Manure. American Society of Agricultural Engineers. Paper No. 72-499. Presented at the 1972 summer meeting in Hot Springs, Arkansas. June 27-30, 1972. In press. 1972.

4. Person, H. L. Performance of Three Hydraulic Systems for Conveying and Treating Swine Manure. Unpublished M.S. Thesis. Iowa State University Library, Ames, Iowa. 153 pp. 1972.

5. Parker, G. B., R. J. Smith, R. S. Blough, and A. R. Mann. The Use of an Induced Aspiration Aeration Device for Winter Operation of Unprotected Aerated Lagoons. American Society of Agricultural Engineers. Paper No. MC-73-303. Presented at the 1972 Mid-Central Regional Meeting in St. Joseph, Missouri. April 6-7, 1973.

SECTION X

APPENDICES

Page

A. Analytical Procedures 114

B. Record of Animal Numbers and Weights in the Individual Systems 116

C. Water Quality Data for the Various Flow Streams 120

D. List of Abbreviations used in the Appendix Tables 147

APPENDIX A

ANALYTICAL PROCEDURES

Sampling procedure

All samples were grab samples placed in 500-ml plastic bottles and taken to the laboratory for analysis within 30 minutes or stored in a refrigerator for analysis the next day. From July 22 until the end of October samples were taken every week.

The 12-m aeration basin sample was taken within 1 m of the edge of the basin. The sample from the lagoon in the lagoon aeration basin was taken from a dock that extended 4 m from the waters edge into the lagoon and was located where the lagoon effluent enters the aeration basin. The aeration basin sample was taken within 1 m of the edge of the 6-m basin. The RBC influent sample was taken from the overflow pipe which controls the water level in the RBC wet well. The RBC effluent sample was taken from the clarifier where the effluent enters the effluent return line.

Water analysis

Biochemical oxygen demand and chemical oxygen demand. The BOD and COD determinations were made according to Standard Methods[27].

Total and volatile solids. The procedure for residue on evaporation and total volatile and fixed residue outlined in Standard Methods[27] was followed.

Ammonia nitrogen. Ammonia-N was determined according to Bremmer and Keeney.[28] Distillation was continued until 50 ml of distillate were collected. A 20-ml sample was used. The distillate was titrated with 0.02N sulfuric acid.

Nitrate and nitrite nitrogen. After the ammonia-N had been distilled from the sample Devarda's alloy was added to the sample. Fifty ml of distillate was collected then titrated as in the ammonia-N determination.

Kjeldahl nitrogen. The procedure for determinating Kjeldahl-N described in Standard Methods[27] was used except that copper selenite was used for the catalyst instead of mercuric sulphate. The following modifications were also made: 20-ml samples were used, ammonia was not removed, 10 ml of 2 percent boric acid was used, and 50 ml of distillate was collected. Organic nitrogen was then calculated by subtracting the ammonia concentration from the Kjeldahl-N concentration.

Total-phosphorus. The method described by Murphy and Riley[29] was used. The reagents used were distributed by Hach Chemical Company, Ames, Iowa. All samples were diluted to contain 0-1 mg/l of total phosphate before they were digested.

Chlorides. Chlorides were measured using the mercuric nitrate/diphenylcarbazone method outlined in Standard Methods[27]. To overcome interference from sulfates, 2 ml of a 50 g/l barium nitrate solution and a 2 ml of a 1 in 4 dilution of concentrated nitric acid solution were added to a 50-ml sample. The sample was then shaken vigorously for one minute, let settle for 30 minutes, then centrifuged for 2 minutes. The supernatant was then titrated as per Standard Methods.

pH. The pH was measured with a Fisher model 320 expanded scale research pH meter in the laboratory.

Dissolved oxygen and temperature. The D.O. and temperature were measured at the waste treatment location using a Yellow Springs Model 40 oxygen meter.

APPENDIX B

RECORD OF ANIMAL NUMBERS AND WEIGHTS IN THE INDIVIDUAL SYSTEMS

Table 13. WEIGHTS OF ANIMALS IN THE AERATION BASIN SYSTEM FOR VARIOUS DATES

Date	# sows	Total wt. (kg)
8-26-71	13	3,170
8-27-71	13	3,170
8-30-71	13	3,170
8-31-71	7	1,680
9-3-71	20	4,710
9-13-71	27	6,710
9-17-71	28	7,020
9-21-71	22	5,800
9-24-71	26	6,700
9-28-71	26	6,410
10-2-71	28	6,990
10-12-71	28	6,950
10-15-71	28	7,040
10-25-71	23	5,460
11-9-71	21	5,010
2-9-72	24	5,940
2-29-72	28	6,930
3-13-72	18	4,450
3-21-72	14	3,460
4-11-72	27	6,680
4-24-72	25	6,190
5-1-72	7	1,730

Table 14. WEIGHT OF ANIMALS IN THE LAGOON-AERATION BASIN SYSTEM FOR VARIOUS DATES

Date	# sows	Total wt. (kg)
8-26-71	47	9,070
8-27-71	46	8,870
8-30-71	40	7,720
8-31-71	26	5,020
9-2-71	24	4,010
9-13-71	24	4,140
9-17-71	32	6,120
9-21-71	24	4,260
9-24-71	23	4,580
9-28-71	15	2,810
10-2-71	12	2,150
10-12-71	10	1,850
10-15-71	10	1,850
1-26-72	7	1,310
2-9-72	28	5,250
2-29-72	42	7,880
3-13-72	28	5,250
3-27-72	35	6,560
4-11-72	21	3,940
4-20-72	21	3,940
4-24-72	21	3,940
5-1-72	2	375

Table 15. WEIGHT OF ANIMALS IN THE RBC SYSTEM FOR VARIOUS DATES

Date	# hogs	Total wt. (kg)
5-19-71	40	590
5-26-71	40	790
6-2-71	89	1,720
6-9-71	89	2,090
6-16-71	88	2,440
6-23-71	88	2,800
6-30-71	85	3,100
7-7-71	85	3,490
7-14-71	84	3,850
7-21-71	84	4,240
7-28-71	85	4,660
8-4-71	85	5,090
8-11-71	85	5,530
8-18-71	85	6,000
8-25-71	67	4,790
9-1-71	67	5,200
9-8-71	44	3,360
9-15-71	153	8,750
9-22-71	117	6,180
9-19-71	117	6,790
10-6-71	80	3,960
10-13-71	78	4,250
10-20-71	78	4,620
11-3-71	534	35,780
11-10-71	534	37,020
11-17-71	425	26,120
11-24-71	425	31,420
12-1-71	424	32,090
12-8-71	424	32,820
12-17-71	215	16,420

Table 15 (continued). WEIGHT OF ANIMALS IN THE RBC SYSTEM FOR VARIOUS DATES

Date	# hogs	Total wt. (kg)
12-24-71	215	16,880
1-8-72	469	31,060
1-15-72	557	31,250
1-22-72	557	34,440
1-29-72	557	37,220
2-5-72	553	35,950
2-12-72	592	30,342
2-19-72	592	24,960
2-26-72	558	15,200
3-4-72	536	15,170

APPENDIX C

WATER QUALITY DATA FOR THE VARIOUS FLOW STREAMS

Table 16. RBC INFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
7-24-71	-	630	-	45.0	-	-	-	-	7.8	-	-
7-27-71	-	820	101.0	47.5	119.0	105.0	-	14.0	7.9	-	-
7-27-71	-	820	101.0	50.0	116.0	91.0	-	25.0	7.9	-	-
7-28-71	-	730	77.0	36.8	126.0	106.0	-	20.0	7.8	2365	755
7-30-71	-	730	119.0	42.5	126.0	106.0	-	20.0	7.8	-	-
8-3-71	-	547	114.0	41.2	-	84.0	-	-	7.8	-	-
8-5-71	-	579	105.0	43.6	105.0	81.0	-	24.0	7.8	-	-
8-7-71	-	560	104.0	37.2	-	-	-	-	7.9	2000	500
8-12-71	250	610	116.0	51.3	-	-	-	-	7.8	-	-
8-14-71	-	610	112.0	48.0	-	106.0	-	-	7.7	2000	515
8-17-71	-	643	93.0	56.0	-	111.0	-	-	7.8	2085	570
8-19-71	250	584	98.0	56.0	124.0	114.0	7.7	10.0	7.9	2005	460
8-22-71	-	596	100.0	46.0	135.0	119.0	7.0	16.0	7.8	-	675
8-24-71	205	555	110.0	-	143.0	128.0	2.1	15.0	7.8	1985	505
8-26-71	280	636	107.0	49.0	151.0	134.0	2.8	17.0	7.8	2055	510
8-30-71	-	656	112.0	50.0	-	140.0	8.4	-	7.9	2105	595
9-3-71	-	466	93.0	36.5	-	133.0	9.4	-	7.8	2040	495
9-10-71	-	531	122.0	45.0	127.0	78.8	9.4	48.2	7.9	2080	535
9-13-71	120	455	105.0	51.0	-	90.6	0.7	-	-	2020	490
9-17-71	147	497	93.0	56.0	123.0	120.0	1.4	54.0	8.1	2115	600

Table 16 (continued). RBC INFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
9-21-71	119	505	112.0	34.0	130.0	115.0	2.8	15.0	8.2	2070	545
9-24-71	-	493	107.0	45.0	131.0	105.0	2.1	26.0	8.3	2210	740
9-28-71	120	463	107.0	46.5	131.0	112.0	0.7	19.0	8.2	2095	605
10-1-71	106	426	103.0	-	125.0	105.0	-	20.0	-	2120	610
10-8-71	-	456	103.0	4.3	123.0	-	1.4	-	8.1	2140	620
10-13-71	100	446	111.0	56.0	116.0	102.9	-	13.1	-	2120	580
10-15-71	116	448	103.0	62.0	-	102.1	1.4	-	8.1	2250	710
10-19-71	88	412	102.0	43.0	108.0	94.0	0.7	14.0	8.0	2140	630
10-26-71	86	475	102.0	50.0	109.0	87.5	2.1	21.5	8.0	2165	645
11-2-71	100	377	97.0	26.5	93.9	71.4	1.4	22.5	8.1	2015	570
11-9-71	-	581	-	50.0	91.0	72.1	1.4	18.9	8.1	2085	870
12-2-71	250	830	115.0	-	127.1	103.5	0.7	23.6	8.0	2430	830
12-6-71	255	1010	120.0	60.0	133.0	116.9	0.7	16.1	7.9	2590	915
12-13-71	357	-	126.0	-	168.0	128.5	-	39.5	8.0	2670	905
12-20-71	-	1460	143.5	71.5	250.0	177.0	-	73.0	7.9	2935	975
1-5-72	685	1850	176.0	50.0	300.0	200.0	0.7	20.0	7.8	3245	1140
1-12-72	670	2020	189.0	69.5	337.0	275.0	0.7	62.0	7.9	2560	1480
1-19-72	920	2336	207.0	71.5	384.0	305.0	0.7	79.0	8.0	3695	1465
1-26-72	-	2004	-	79.5	446.6	369.6	-	77.0	7.9	3975	1545
2-2-72	1190	3000	223.0	85.0	496.0	403.0	-	93.0	7.8	-	-

Table 16 (continued). RBC INFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
2-9-72	1545	3160	254.0	82.5	517.0	440.0	-	77.0	7.9	4395	1680
2-15-72	-	-	-	-	-	486.0	-	-	-	-	-
2-16-72	1740	3500	316.0	82.0	-	-	-	66.0	8.0	4830	1970
2-29-72	1620	3615	333.0	125.0	-	-	2.1	-	8.1	5120	2180
3-8-72	-	274	-	139.0	694.0	-	-	522.0	7.9	-	-
3-13-72	-	4400	324.0	53.0	710.0	336.0	-	374.0	7.8	-	-
3-20-72	1800	4000	308.0	110.0	677.0	569.0	-	108.0	7.8	-	-
4-2-72	-	2818	226.0	66.0	-	-	-	-	7.8	3795	1555
4-11-72	2280	3490	220.0	75.0	508.0	440.0	-	68.0	7.8	3850	1450
4-20-72	-	2755	226.0	66.0	455.0	414.4	-	40.6	7.8	3700	1470
4-24-72	1640	2660	222.0	80.0	501.0	428.0	-	73.0	7.9	3840	1680
5-1-72	1520	2713	220.0	58.0	477.4	417.2	-	60.2	8.0	3740	1625
6-14-72	-	2645	262.0	93.0	407.0	375.0	-	-	7.8	4890	-
6-19-72	1170	2435	246.0	100.0	254.0	208.0	-	-	7.8	-	-
6-26-72	1830	2460	240.0	120.0	410.0	382.0	4.0	-	7.5	4732	2628
7-6-72	1100	3148	244.0	110.0	476.0	414.0	1.0	-	7.7	4550	2370
7-11-72	1560	2680	254.0	139.0	-	-	-	-	7.3	4340	2210
7-25-72	375	1164	120.0	75.0	147.0	111.0	3.0	-	7.8	2565	1030
8-1-72	570	990	185.0	86.0	199.0	157.0	4.0	-	7.4	2620	1120

Table 16 (continued). RBC INFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
8-9-72	1500	2445	239.0	130.0	460.0	417.0	7.0	-	7.6	4530	2480
8-16-72	2360	2500	244.0	170.0	520.0	453.0	20.0	-	7.3	5890	2575
8-24-72	1620	2870	256.0	198.0	540.0	496.0	8.0	-	7.4	4840	2580
9-7-72	765	2520	273.0	165.0	616.0	507.0	3.0	-	7.5	4460	2240
9-15-72	800	2310	260.0	139.0	571.0	498.0	11.0	-	7.3	-	-

Table 17. RESULTS OF WATER QUALITY ANALYSES CONDUCTED ON THE RBC LAGOON SUPERNATANT INCLUDING THE TIME THIS WATER WAS NOT SERVING AS RBC INFLUENT

Date	COD	NH_3	Kjeld-N	NO_3	BOD	Total solids	Volatile solids	Cl	PO_4	pH
6-14-72	2380	340	410	-	1060	4200	-	290	50	7.8
6-19-72	2300	210	240	-	1140	-	-	250	-	7.8
6-26-72	2460	370	430	3	1500	4250	2350	240	140	7.7
7-6-72	-	410	470	3	1200	4340	2265	270	110	7.5
7-11-72	2720	-	-	-	1340	4180	2060	260	120	7.5
7-25-72	2490	230	290	-	1680	3875	1880	200	100	7.6
8-1-72	1780	280	330	4	1125	3604	1700	216	120	7.2
8-9-72	2800	430	490	1	1440	4340	2330	240	160	7.7
8-16-72	2960	450	520	3	2130	5550	2380	250	180	7.4
8-24-72	2600	500	580	-	1620	4560	2380	250	150	7.5
9-7-72	2670	510	590	6	1030	4580	2130	250	140	7.7
9-15-72	2310	500	570	11	800	-	-	140	260	7.3
9-22-72	2120	500	570	8	600	3810	1700	260	100	7.7
9-28-72	2030	500	-	10	820				130	7.6
11-3-72	1750	460	543	-	730	-	-	-	-	-
11-16-72	1580	430	500	-	460	3480	1680			

Table 18. RBC INFLUENT TEMPERATURE AND DISSOLVED OXYGEN DATA

Date	Temperature, °C	D.O., mg/1
8-5-71	19.0	-
8-12-71	20.0	-
8-30-71	20.0	-
9-3-71	21.5	-
9-21-71	13.5	-
9-24-71	14.0	-
10-8-71	14.0	-
10-13-71	11.0	-
10-15-71	13.0	-
10-19-71	16.5	-
10-26-71	14.8	-
11-2-71	9.8	-
11-9-71	3.0	-
12-6-71	3.0	-
12-20-71	4.0	3.4
12-20-71	4.0	3.4
2-2-72	5.0	-
2-29-72	5.1	0.9
3-20-72	7.0	0.9
4-2-72	4.0	2.5
4-11-72	7.0	4.2
4-20-72	11.4	2.4
4-24-72	10.0	3.5
8-9-72	-	0.8
8-16-72	2.5	0.4
8-24-72	19.0	0.4
9-7-72	21.0	2.1

Table 19. RBC EFFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
7-24-71	580	522	-	-	-	-	-	-	8.0	-	-
7-27-71	-	676	93.0	50.0	116.0	91.0	-	25.0	8.1	-	-
7-27-71	-	-	-	38.5	-	-	-	-	-	-	-
7-28-71	300	-	-	-	-	-	-	-	-	-	-
7-30-71	-	540	82.0	43.8	-	-	-	-	8.0	2280	650
8-3-71	-	462	82.0	39.8	-	-	-	12.6	8.0	-	-
8-5-71	-	474	87.0	43.6	102.0	80.0	-	22.0	8.0	-	-
8-7-71	-	475	81.0	34.8	-	-	-	-	8.0	2005	485
8-12-71	250	510	84.0	45.3	120.0	-	-	-	8.0	-	-
8-14-71	-	485	83.0	41.3	120.0	106.0	-	14.0	8.1	1995	515
8-17-71	-	520	100.0	45.2	-	114.0	-	55.0	8.1	2085	550
8-19-71	140	453	98.0	52.5	-	109.0	4.2	-	8.1	2000	450
8-22-71	-	440	95.0	42.4	132.0	116.0	8.4	16.0	8.0	2090	565
8-24-71	114	425	90.0	42.4	136.0	122.0	5.6	14.0	8.1	1985	480
8-26-71	170	455	115.0	41.0	143.0	130.0	4.2	13.0	8.1	2040	495
8-30-71	-	460	92.0	45.0	-	134.0	5.6	-	8.2	2050	515
9-3-71	-	350	89.0	40.0	143.0	127.0	1.4	16.0	8.0	2020	445
9-10-71	-	336	102.0	38.0	-	123.0	1.4	-	8.1	2050	460
9-13-71	49	354	105.0	50.0	-	-	-	-	-	-	-
9-17-71	77	392	100.0	50.0	122.0	106.0	1.4	16.0	8.2	2145	540

Table 19 (continued). RBC EFFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
9-21-71	54	384	112.0	62.0	126.0	116.0	4.2	10.0	8.2	2030	535
9-24-71	-	392	105.0	50.0	126.0	111.0	2.1	15.0	8.2	2240	560
9-28-71	65	268	106.0	32.0	122.0	111.0	2.8	11.0	8.2	2050	550
10-1-71	78	338	103.0	-	119.0	102.0	2.8	17.0	-	2040	540
10-8-71	-	397	106.0	50.0	99.5	82.6	22.8	16.9	8.0	2085	570
10-13-71	90	416	102.0	50.0	-	74.1	17.1	-	-	2140	605
10-15-71	128	416	102.0	65.0	-	72.8	16.8	-	7.9	2215	645
10-19-71	70	382	-	62.0	74.4	62.2	23.4	12.2	7.9	2140	620
10-26-71	75	423	109.0	51.0	71.5	54.6	28.6	16.9	7.9	2120	610
11-2-71	50	296	-	40.0	29.4	20.3	47.6	9.1	7.7	1995	545
11-9-71	-	388	-	55.5	56.0	48.2	0.7	7.8	7.9	2190	630
11-19-71	-	-	-	50.0	-	-	-	-	-	-	-
11-20-71	-	267	106.0	-	66.8	49.0	27.3	17.8	7.0	-	-
12-2-71	115	590	113.0	-	110.5	88.4	7.7	22.1	7.8	2265	695
12-6-71	125	703	122.0	51.0	127.2	106.1	0.7	21.1	7.8	2385	760
12-13-71	185	785	125.0	38.4	155.0	121.0	0.7	34.0	7.9	2445	780
12-20-71	-	-	143.5	50.0	226.2	164.0	0.7	62.2	8.0	2745	655
1-5-72	525	1770	178.0	69.5	304.0	243.0	0.7	61.0	7.9	3195	1140
1-12-72	820	2140	194.0	99.0	327.0	268.0	0.7	59.0	8.0	3560	1345
1-19-72	860	2448	224.0	85.0	383.0	380.0	-	-	7.8	3725	1505

Table 19 (continued). RBC EFFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
1-26-72	-	2604	-	92.0	446.6	360.5	-	86.1	8.1	-	1305
2-2-72	1070	2900	218.0	85.0	479.0	394.0	-	85.0	8.0	-	-
2-9-72	1500	3090	274.0	96.0	557.0	475.0	-	82.0	8.0	4315	1670
2-12-72	-	2080	-	-	-	465.0	-	-	7.1	-	-
2-16-72	1490	3340	272.0	90.5	-	-	0.7	134.0	8.0	4610	1900
2-29-72	1500	5615	287.0	98.0	-	-	-	-	8.3	4870	2150
3-8-72	-	-	-	102.0	675.0	-	-	497.0	8.2	-	-
3-13-72	-	4210	306.0	84.0	674.0	-	-	487.0	8.0	-	-
3-20-72	1860	3850	282.0	53.0	664.0	576.0	-	88.0	8.1	-	-
4-2-72	-	2425	224.0	69.0	-	-	-	-	7.9	3710	1530
4-11-72	2080	2551	218.0	58.0	498.0	427.6	-	70.4	8.0	3660	1455
4-20-72	-	2571	208.0	58.0	488.0	422.8	-	65.2	8.1	3615	1490
4-24-72	1500	2579	222.0	61.0	494.0	420.0	-	74.0	-	3740	1575
5-1-72	1400	2512	222.0	55.0	469.0	403.2	-	65.8	8.2	3615	1545
6-14-72	1095	2385	242.0	75.0	372.0	361.0	-	-	8.2	4320	-
6-19-72	965	2355	229.0	50.0	238.0	203.0	-	-	8.1	-	-
6-26-72	1350	2220	231.0	66.0	430.0	366.0	3.0	-	8.1	4240	2300
7-6-72	800	-	242.0	66.0	457.0	393.0	4.0	-	8.1	4260	2140
7-11-72	1180	2640	261.0	66.0	-	-	-	-	8.0	3590	1980
7-25-72	372	1206	139.0	73.0	182.0	146.0	1.0	-	8.0	2580	1060

Table 19 (continued). RBC EFFLUENT WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
8-1-72	290	930	149.0	64.0	188.0	158.0	4.0	-	7.9	2416	932
8-9-72	820	2100	228.0	69.0	460.0	384.0	4.0	-	8.4	3800	1940
8-16-72	1160	2000	237.0	73.0	442.0	370.0	6.0	-	8.4	3500	1610
8-24-72	600	2180	256.0	77.0	481.0	386.0	-	-	8.4	3820	1760
9-7-72	246	2040	258.0	96.0	583.0	440.0	-	-	8.5	3630	1590
9-15-72	305	1940	252.0	84.0	-	459.0	3.0	-	8.4	-	-

Table 20. RBC EFFLUENT TEMPERATURE AND DISSOLVED OXYGEN DATA

Date	Temperature, °C	D.O., mg/l
8-5-71	18.0	-
8-7-71	16.5	-
8-30-71	18.4	0.3
9-3-71	20.4	0.2
9-13-71	-	-
9-21-71	15.0	2.9
9-24-71	13.5	3.2
10-5-71	16.7	2.5
10-8-71	14.0	1.0
10-13-71	11.1	1.5
10-15-71	11.9	-
10-19-71	16.7	0.3
10-26-71	15.0	1.3
11-2-71	9.0	3.0
11-9-71	3.0	-
11-19-71	6.0	3.5
12-6-71	4.0	-
12-20-71	4.0	0.7
1-5-72	5.0	0.8
1-12-72	5.5	0.8
2-2-72	6.1	0.6
2-29-72	6.1	0.7
3-20-72	8.5	0.3
4-2-72	4.6	0.5
4-11-72	7.0	0.4
4-20-72	11.4	1.0
4-24-72	9.5	0.5
8-9-72	-	0.8
8-16-72	25.0	0.4
8-24-72	19.0	0.4
9-7-72	21.0	2.1

Table 21. TWELVE METER AERATION BASIN WATER ANALYSIS DATA

Date	BOD	COD	CL	PO$_4$	KJELD	NH$_4$	NO$_3$	ORG-N	pH	T-solid	VSOL
7-24-71	-	915	-	-	-	-	-	-	8.1	-	-
7-28-71	250	408	76.0	75.5	-	39.0	-	64.0	8.5	3060	1135
7-30-71	-	-	-	-	-	-	-	-	-	-	-
8-3-71	-	400	82.0	65.0	39.2	29.4	-	9.8	8.5	-	-
8-5-71	-	337	81.0	75.5	52.0	32.0	-	20.0	8.6	-	-
8-7-71	-	790	-	69.0	-	-	-	-	8.0	2760	925
8-12-71	320	670	-	43.8	54.0	-	-	-	8.3	-	-
8-14-71	-	735	83.0	76.0	42.0	3.0	-	39.0	8.4	2735	825
8-17-71	-	-	82.0	115.0	50.0	-	-	50.0	8.3	3055	1015
8-19-71	200	615	-	77.0	16.0	2.0	51.9	14.0	8.3	2910	855
8-22-71	-	596	96.0	85.0	48.0	3.0	49.0	45.0	8.4	3085	1080
8-24-71	155	780	-	-	15.0	-	-	-	8.4	3045	985
8-26-71	245	-	92.0	90.0	21.0	3.0	49.0	18.0	8.4	3090	1000
8-30-71	-	342	92.0	100.0	19.6	4.0	63.0	15.6	8.4	2980	1210
9-3-71	-	592	92.0	90.0	40.0	7.0	52.0	33.0	8.4	2675	1020
9-10-71	-	633	102.0	80.0	32.2	0.7	43.4	31.5	8.3	3130	985
9-13-71	122	697	105.0	93.0	44.1	0.7	35.8	43.4	-	3275	1025
9-17-71	136	495	107.0	154.0	38.0	0.7	59.5	37.3	8.5	3735	1320
9-21-71	108	414	110.0	127.0	-	-	36.1	-	8.4	3625	1275
9-24-71	-	956	97.0	149.0	54.6	1.4	32.9	53.2	8.5	4255	1750

Table 21 (continued). TWELVE METER AERATION BASIN WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
9-28-71	111	628	94.0	100.0	-	2.8	45.5	101.2	-	3410	1195
10-1-71	168	1090	98.0	-	63.0	2.8	44.9	60.2	-	4170	1525
10-8-71	-	1321	98.0	181.0	67.0	2.1	118.0	64.9	-	4560	1860
10-13-71	280	1620	102.0	154.0	68.6	1.4	67.9	67.2	-	5030	2075
10-15-71	-	1669	110.0	237.0	-	2.8	121.0	42.7	-	5225	2240
10-19-71	-	-	100.0	237.0	108.0	1.4	81.3	106.6	-	5685	2570
10-26-71	-	2910	97.0	245.0	136.0	3.5	48.4	132.5	-	6245	2905
11-2-71	-	286	84.0	43.0	-	1.4	143.0	11.2	-	3060	1140
11-9-71	260	480	-	43.0	-	46.1	51.7	12.7	-	2735	960
11-20-71	-	693	90.0	50.0	120.3	94.5	2.1	25.8	-	-	-
12-2-71	322	760	126.8	-	93.8	68.6	-	25.2	7.6	2330	755
12-6-71	283	712	124.0	61.5	82.6	64.4	-	18.2	7.6	2335	755
12-13-71	265	627	115.0	33.6	84.0	29.3	1.4	54.7	7.5	2235	685
12-20-71	-	611	109.0	58.5	78.4	53.9	1.4	24.5	7.6	2145	620
1-5-72	120	439	109.0	30.5	61.8	44.7	0.7	17.1	7.6	1970	525
1-12-72	100	349	97.0	39.8	42.0	39.2	0.7	2.8	7.7	1475	495
2-9-72	128	257	79.0	25.0	42.0	33.5	-	8.5	7.8	1775	225
2-25-72	-	250	72.0	-	-	31.5	1.4	-	7.0	1720	295
2-29-72	-	64	-	8.3	4.2	2.1	3.5	2.1	7.5	-	100
3-8-72	-	19	-	20.0	26.6	18.9	-	7.7	7.2	-	-

Table 21 (continued). TWELVE METER AERATION BASIN WATER ANALYSIS DATA

Date[1]	BOD	COD	CL	PO_4	KJELD	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
3-13-72	-	-	67.0	25.0	36.4	28.7	-	7.7	7.3	-	-
3-20-72	308	693	80.0	13.5	96.9	44.8	-	52.1	7.7	-	-
4-2-72	200	1005	75.0	58.0	-	-	-	-	-	2570	840
4-11-72	605	939	72.0	55.0	83.5	33.8	-	49.7	7.8	2650	835
4-20-72	-	469	80.0	64.0	74.2	21.0	-	53.2	7.5	2605	825
4-24-72	285	929	-	64.0	-	9.8	-	-	7.5	2670	845
5-1-72	368	955	72.0	50.0	50.4	3.5	-	46.9	7.7	2575	845
6-14-72	200	920	70.0	80.0	50.0	3.0	-	-	7.8	3340	-
6-19-72	100	570	80.0	80.0	30.0	20.0	-	-	7.9	-	-
6-26-72	110	880	80.0	70.0	60.0	2.0	11.0	-	8.0	2906	1080
7-6-72	120	930	70.0	80.0	60.0	4.0	6.0	-	7.9	3030	1070
7-11-72	170	870	70.0	110.0	-	-	-	-	7.7	3060	1070
8-9-72	130	500	250.0	60.0	30.0	5.0	34.0	-	7.8	2080	660
8-16-72	175	420	60.0	50.0	20.0	2.0	38.0	-	7.9	2120	940
8-24-72	100	380	70.0	50.0	30.0	10.0	30.0	-	7.8	2180	610
9-7-72	40	430	80.0	50.0	30.0	3.0	21.0	-	8.0	2100	570
9-15-72	40	350	70.0	40.0	-	4.0	30.0	-	7.9	-	-
9-22-72	40	390	70.0	40.0	30.0	1.0	36.0	-	7.7	2170	570
9-28-72	40	330	-	50.0	-	10.0	70.0	-	7.9	-	-
11-3-72	100	360	-	-	31.0	4.0	40.0	-	-	-	
11-16-72	20	110	-	-	11.0	3.0	36.0	-	-	1420	340

Notes: 1. No manure added to this system after August 1, 1972.

Table 22. TWELVE METER AERATION BASIN TEMPERATURE AND DISSOLVED OXYGEN DATA

Date	Temperature, ^{o}C	D.O., mg/1
7-24-71	20.0	-
8-5-71	16.0	-
8-14-71	19.0	-
8-30-71	1.6	7.6
9-3-71	2.1	7.1
9-13-71	17.3	8.5
9-21-71	12.2	8.8
9-24-71	10.0	9.8
10-8-71	10.2	8.4
10-13-71	8.5	8.8
10-15-71	10.0	9.8
10-19-71	17.2	7.1
10-26-71	15.0	7.5
11-2-71	6.5	6.3
11-9-71	7.0	0.9
11-20-71	8.0	1.1
12-6-71	4.5	-
12-20-71	3.0	0.5
12-2-71	-	-
12-6-71	4.5	-
12-13-71	-	-
12-20-71	3.0	0.5
12-20-71	3.0	0.5
1-12-72	3.4	0.9
2-9-72	-	-
2-29-72	5.2	0.9
3-20-72	9.0	5.5
4-2-72	3.0	7.1
4-11-72	6.0	11.6
4-20-72	10.0	7.9
4-24-72	7.0	9.4

Table 23. ANAEROBIC LAGOON SUPERNATANT OF THE ANAEROBIC LAGOON-AERATION BASIN SYSTEM CHEMICAL DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
7-24-71	-	370	-	-	-	-	-	-	7.9	-	-
7-28-71	125	-	73.0	28.6	-	-	-	-	8.1	-	725
8-3-71	-	221	73.0	20.0	12.7	8.4	-	4.3	8.5	-	-
8-5-71	-	274	71.0	25.0	27.0	11.0	-	16.0	8.2	-	-
8-7-71	-	274	73.0	16.0	-	-	-	-	8.3	1535	505
8-12-71	200	-	70.0	20.0	48.0	-	-	-	8.3	-	-
8-14-71	-	-	78.0	20.0	29.0	14.0	-	15.0	8.4	1505	535
8-17-71	-	337	93.0	25.0	41.0	15.0	-	26.0	8.4	1545	575
8-19-71	75	344	87.0	21.0	22.4	14.0	7.7	8.4	8.6	1565	520
8-22-71	-	326	76.0	20.0	33.0	19.0	7.7	14.0	8.4	1575	595
8-24-71	88	344	80.0	-	32.0	21.0	7.0	11.0	8.3	1510	570
8-26-71	200	364	90.0	22.0	38.0	25.0	7.0	13.0	8.4	-	-
8-30-71	-	382	85.0	25.0	38.0	28.0	5.6	10.0	8.1	1710	630
9-3-71	-	320	82.0	29.0	38.0	17.8	1.4	20.2	8.1	1745	595
9-10-71	-	362	90.0	43.0	19.6	12.3	1.4	7.3	8.1	1780	565
9-13-71	91	374	95.0	40.0	30.7	11.5	1.4	19.2	-	1710	540
9-17-71	94	382	102.0	46.0	35.0	11.9	0.7	23.1	8.3	1900	635
9-21-71	114	424	100.0	43.0	49.2	15.4	2.8	33.8	8.5	1830	625
9-24-71	-	438	97.0	36.0	53.3	14.0	1.4	39.3	8.3	1930	650
9-28-71	136	388	94.0	46.5	37.8	13.0	1.4	24.8	8.1	1865	655

Table 23 (continued). ANAEROBIC LAGOON SUPERNATANT OF THE ANAEROBIC LAGOON-AERATION BASIN SYSTEM CHEMICAL DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
10-1-71	132	441	98.0	-	42.0	13.3	0.7	28.7	-	1880	635
10-8-71	-	397	101.0	43.0	40.6	14.7	2.1	25.9	8.2	1870	610
10-13-71	125	380	102.0	45.0	30.1	17.1	-	13.0	-	1930	590
10-15-71	168	354	100.0	42.0	-	21.0	1.4	-	8.3	1950	650
10-19-71	196	392	100.0	38.0	36.4	20.2	0.4	16.2	8.1	1995	670
10-26-71	140	423	-	43.0	42.0	19.6	2.1	22.4	8.2	2020	715
11-2-71	80	357	88.0	37.5	25.2	14.7	6.3	10.5	7.8	1720	600
11-9-71	121	265	-	22.0	26.6	15.4	9.1	11.2	8.0	1735	585
11-20-71	-	277	89.0	25.0	30.8	21.7	8.4	9.1	7.8	-	-
12-2-71	34	240	96.1	-	36.4	27.7	4.2	8.7	8.0	1745	510
12-6-71	33	268	96.0	37.5	27.8	27.2	2.8	0.6	7.8	1750	565
12-13-71	44	255	96.0	32.5	40.6	28.6	1.4	12.0	7.7	1845	500
12-20-71	-	292	99.0	38.5	43.8	30.8	2.1	13.0	7.7	1850	455
1-5-72	46	410	108.0	51.0	47.5	34.3	2.1	13.2	7.6	1990	465
1-12-72	42	242	95.0	41.6	51.9	30.1	-	21.8	8.8	2260	550
1-19-72	-	-	-	-	-	-	-	-	7.6	-	-
2-2-72	61	314	100.0	49.4	53.1	40.6	0.7	12.5	7.6	-	-
2-9-72	85	298	107.0	45.2	57.5	45.0	-	12.5	7.6	2015	365
2-25-72	-	315	101.5	-	39.9	21.0	0.7	18.9	-	2020	470

Table 23 (continued). ANAEROBIC LAGOON SUPERNATANT OF THE ANAEROBIC LAGOON-AERATION BASIN SYSTEM CHEMICAL DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
2-29-72	-	216	67.0	26.2	23.8	18.5	3.5	5.3	7.9	1240	-
3-8-72	-	-	-	96.0	-	122.0	-	-	7.5	-	-
3-20-72	160	366	82.0	115.0	70.0	56.0	-	14.0	7.7	-	-
4-2-72	80	333	83.0	33.3	-	-	-	-	7.7	1775	300
4-11-72	234	1214	83.0	30.5	74.2	63.4	-	10.8	7.8	1635	310
4-20-72	-	235	86.0	32.0	74.2	61.6	-	12.6	7.7	1640	345
4-24-72	81	252	84.0	32.0	72.9	60.1	-	12.8	7.7	1875	335
5-1-72	100	226	81.0	32.0	63.0	53.2	-	9.8	-	1765	300
6-14-72	50	250	80.0	30.0	20.0	20.0	-	-	8.1	2060	-
6-19-72	70	300	90.0	40.0	20.0	30.0	-	-	7.8	-	-
6-26-72	120	300	80.0	50.0	50.0	28.0	3.0	-	7.7	2080	700
7-6-72	100	130	90.0	50.0	50.0	13.0	-	-	7.2	1950	560
7-11-72	110	470	90.0	50.0	-	-	-	-	7.9	2030	570
8-9-72	310	700	100.0	60.0	120.0	90.0	6.0	-	8.0	1910	712
8-16-72	210	430	100.0	40.0	90.0	70.0	4.0	-	8.0	1780	690
8-24-72	200	350	100.0	40.0	80.0	70.0	10.0	-	7.5	1770	500
9-7-72	45	300	90.0	40.0	70.0	80.0	4.0	-	7.8	1710	460
9-15-72	30	220	90.0	30.0	-	40.0	3.0	-	7.9	-	-
9-22-72	30	230	90.0	30.0	50.0	40.0	3.0	-	7.6	1670	360

Table 23 (continued). ANAEROBIC LAGOON SUPERNATANT OF THE ANAEROBIC LAGOON-AERATION BASIN SYSTEM CHEMICAL DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
9-28-72	20	200	-	30.0	140.0	60.0	20.0	-	8.0	-	-
11-3-72	210	110	-	-	27.0	13.0	-	-	-	-	-
11-16-72	14	90	-	-	15.0	6.0	-	-	-	1750	300

Notes:
1. No additional manure discharged to this system after August 1, 1972.

Table 24. ANAEROBIC LAGOON SUPERNATANT TEMPERATURE AND DISSOLVED OXYGEN DATA

Date	Temperature, °C	D.O., mg/l
7-24-71	22.0	-
8-5-71	19.0	-
8-14-71	20.0	-
8-30-71	19.0	0.2
9-13-71	18.8	-
9-21-71	13.4	1.2
9-24-71	12.9	0.5
10-5-71	19.2	0.2
10-8-71	13.0	0.6
10-13-71	10.1	0.5
10-15-71	11.0	-
10-19-71	11.0	0.5
10-26-71	15.3	0.7
11-2-71	7.3	1.4
11-9-71	3.4	5.4
11-20-71	6.0	3.9
12-2-71	-	-
12-6-71	3.0	-
12-13-71	-	-
12-20-71	1.0	0.7
12-20-71	1.0	0.7
1-12-72	1.3	1.4
2-2-72	-	1.3
2-29-71	1.0	2.4
4-2-72	5.8	0.9
4-11-72	7.0	0.9
4-20-72	10.2	1.0
4-24-72	7.0	2.2

Table 25. SIX METER AERATION BASIN WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
7-24-71	-	240	-	-	-	-	-	-	8.7	-	-
7-28-71	75	282	67.0	25.0	-	-	-	-	8.5	1715	580
7-30-71	-	-	-	-	28.0	8.0	-	20.0	-	-	-
8-3-71	-	263	73.0	20.0	-	8.4	-	-	8.7	1485	520
8-5-71	-	253	68.0	23.2	24.0	8.0	-	16.0	8.7	-	-
8-7-71	-	232	72.0	13.7	-	-	-	-	8.8	-	-
8-12-71	100	234	73.0	19.3	25.2	-	-	-	8.6	-	-
8-14-71	-	234	74.0	19.0	25.2	14.0	-	11.2	8.8	1480	530
8-17-71	-	306	87.0	25.0	39.0	13.0	-	26.0	8.5	1565	580
8-19-71	135	333	84.0	25.0	27.3	15.0	7.0	12.3	8.8	1590	495
8-22-71	-	316	84.0	11.2	32.0	15.0	7.7	17.0	8.7	1535	600
8-24-71	80	344	85.0	-	32.0	15.0	8.0	17.0	8.7	1605	570
8-26-71	212	-	95.0	-	42.0	-	-	-	8.0	-	-
8-30-71	-	342	82.0	25.0	16.0	14.0	13.3	-	8.6	1715	610
9-3-71	-	302	77.0	33.0	-	66.0	9.1	-	8.4	1760	575
9-10-71	-	322	90.0	62.0	30.8	9.3	9.2	21.5	8.4	1760	575
9-13-71	122	354	92.0	40.0	30.8	10.5	3.2	20.3	-	1715	540
9-17-71	104	397	92.0	42.0	34.0	11.1	3.1	22.9	8.6	1840	620
9-21-71	117	404	95.0	45.0	47.8	15.4	4.2	32.4	8.6	1850	665
9-24-71	-	392	97.0	42.0	36.4	14.0	1.4	22.4	8.6	1930	720

Table 25 (continued). SIX METER AERATION BASIN WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
9-28-71	148	388	94.0	43.0	35.0	12.0	2.8	23.0	8.5	1865	660
10-1-71	182	411	98.0	-	36.4	11.2	1.4	25.2	-	1865	625
10-8-71	-	368	98.0	42.0	36.0	11.9	-	24.1	8.5	1890	615
10-13-71	142	351	102.0	26.0	33.6	15.4	-	18.2	-	1926	580
10-15-71	215	354	110.0	-	18.9	10.1	1.4	8.8	8.6	1890	555
10-19-71	275	371	100.0	4.0	35.0	17.5	2.1	17.5	8.5	1945	655
10-26-71	160	382	97.0	45.0	47.6	18.2	2.1	29.4	8.6	2025	730
11-2-71	75	276	84.0	37.5	32.2	14.0	7.0	18.2	7.8	1630	580
11-9-71	114	255	-	21.0	21.0	15.4	-	5.6	7.9	1650	570
11-20-71	-	198	90.0	33.0	29.4	22.4	9.1	7.0	7.8	-	-
12-2-71	36	270	94.1	-	36.4	23.8	-	12.6	7.9	1740	530
12-6-71	-	188	-	17.5	25.2	18.9	8.4	6.3	7.6	-	400
12-13-71	48	264	99.0	32.5	39.2	28.0	0.7	11.2	7.7	1765	475
12-20-71	-	233	76.0	24.0	30.8	19.6	7.0	11.2	7.7	1770	395
1-5-72	49	286	106.0	38.5	46.3	34.3	1.4	12.0	7.6	1915	455
1-12-72	28	-	-	22.5	-	14.7	2.1	6.3	8.0	-	280
1-19-72	68	299	109.0	49.5	51.8	39.2	2.1	12.6	7.6	2000	520
2-2-72	76	333	100.0	40.0	53.1	39.2	2.1	13.9	7.6	-	-
2-16-72	109	308	104.0	43.8	-	46.8	0.7	-	7.7	-	345

Table 25 (continued). SIX METER AERATION BASIN WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
2-25-72	-	335	103.5	-	40.6	35.0	-	5.6	-	2047	495
2-29-72	-	-	-	10.0	-	-	2.1	0.7	7.0	-	-
3-8-72	-	264	-	48.0	86.8	68.0	-	18.8	7.6	-	-
3-13-72	-	-	97.0	10.0	89.5	70.7	-	18.8	7.[illegible]	-	-
3-20-72	172	366	84.0	40.0	67.3	55.4	-	11.9	7.7	-	-
4-2-72	56	292	84.0	33.0	-	-	-	-	7.8	1765	355
4-11-72	158	214	83.0	29.0	71.4	47.6	-	23.8	8.1	1810	330
4-20-72	-	235	87.0	30.0	71.4	63.0	-	8.4	8.1	1835	350
4-24-72	79	263	87.0	32.0	71.4	61.0	-	10.4	8.1	1955	360
5-1-72	98	266	83.0	30.5	61.6	24.5	-	37.1	-	1850	320
6-14-72	100	230	80.0	30.0	30.0	20.0	-	-	7.3	2280	-
6-19-72	80	240	90.0	20.0	10.0	40.0	-	-	8.1	-	-
6-26-72	15	130	80.0	20.0	10.0	-	7.0	-	8.4	1760	420
7-6-72	15	20	80.0	20.0	10.0	1.0	10.0	-	8.2	1760	390
7-11-72	15	80	80.0	25.0	-	-	-	-	8.1	1660	330
8-9-72	190	410	180.0	30.0	40.0	30.0	3.0	-	8.1	870	360
8-16-72	380	490	100.0	50.0	100.0	70.0	4.0	-	8.1	1740	740
8-24-72	200	360	110.0	40.0	70.0	60.0	20.0	-	8.2	1730	470
9-7-72	10	270	100.0	130.0	60.0	50.0	4.0	-	8.2	1630	300

Table 25 (continued). SIX METER AERATION BASIN WATER ANALYSIS DATA

Date	BOD	COD	CL	PO_4	Kjeld	NH_4	NO_3	ORG-N	pH	T-solid	VSOL
9-15-72	15	200	90.0	30.0	-	40.0	6.0	-	8.1	-	-
9-22-72	20	200	90.0	30.0	50.0	36.0	7.0	-	8.2	1660	360
9-28-72	30	180	-	30.0	70.0	50.0	10.0	-	8.3	-	-
11-3-72	25	80	-	-	17.0	7.0	21.0	-	-	-	-
11-16-72	27	130	-	-	13.0	3.0	24.0	-	-	1470	330

Table 26. SIX METER AERATION BASIN TEMPERATURE AND DISSOLVED OXYGEN DATA

Date	Temperature, °C	D.O., mg/1
8-5-71	15.0	-
8-7-71	18.0	-
8-30-71	16.3	9.0
9-3-71	21.0	7.8
9-13-71	18.0	8.9
9-21-71	14.0	8.8
9-24-71	12.0	9.6
10-5-71	19.0	7.7
10-8-71	12.5	9.3
10-13-71	10.1	9.6
10-15-71	11.0	6.4
10-19-71	19.0	9.0
10-26-71	15.0	8.8
11-2-71	7.8	1.0
11-9-71	3.0	5.0
11-20-71	7.0	1.7
12-2-71	-	-
12-6-71	3.0	-
12-13-71	-	-
12-20-71	2.0	0.6
12-20-71	2.0	0.6
11-9-71	3.0	5.0
11-20-71	7.0	1.7
12-2-71	-	-
12-6-71	3.0	-
12-13-71	-	-
12-20-71	2.0	0.6
12-20-71	2.0	0.6
1-12-72	2.2	0.8

Table 26 (continued). SIX METER AERATION BASIN TEMPERATURE AND DISSOLVED OXYGEN DATA

Date	Temperature, °C	D.O., mg/l
2-2-72	2.0	3.4
2-29-72	0.1	11.7
3-20-72	1.0	2.5
4-2-72	3.5	6.8
4-11-72	7.0	12.6
4-20-72	10.1	10.2
4-24-72	8.0	10.8

APPENDIX D

LIST OF ABBREVIATIONS USED IN APPENDIX TABLES

SYMBOL	DEFINITION
BOD	Five day biochemical oxygen demand, mg/1
COD	Chemical oxygen demand, mg/1
PO_4	Total phosphate concentration, mg/1
KJELD	Kjeldahl nitrogen concentration which includes ammonia and organic nitrogen, mg/1
Kjeld-N	Kjeldahl nitrogen concentration which includes ammonia and organic nitrogen.
NH_3	Ammonia nitrogen concentration, mg/1
NO_3	Nitrate nitrogen concentration, mg/1
ORG-N	Organic nitrogen concentration, mg/1
pH	Negative logarithm of the hydrogen ion concentration
T-SOLID	Total solids concentration, mg/1
Total solids	Total solids concentration, mg/1
VSOL	Volatile solids concentration, mg/1
Volatile solids	Volatile solids concentration, mg/1
CL	Chloride ion concentration, mg/1
D.O.	Dissolved oxygen, mg/1
-	No data available.